Support to the development of methodologies for the certification of industrial carbon removals with permanent storage

Review of certification methodologies and relevant EU legislation

8 December 2023

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A report submitted by ICF S.A., Cerulogy and Fraunhofer ISI

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Executive summary

In November 2022 the European Commission published a proposal for a Carbon Removal Certification Framework (CRCF). In the context of that proposal, this review considers existing European Union (EU) legislation and of selected certification schemes for GHG emission reductions and/or removals that could inform the development of EU certification methodologies for Bioenergy with Carbon Capture and Storage (BECCS), projects, Direct Air Capture (DAC) with Carbon Storage (DACCS) projects, and other industrial carbon removals projects. This paper will inform the development of carbon removal certification methodologies under the CRCF.

From the review of relevant EU legislation and policies, several existing frameworks have been identified as useful for the certification of carbon removals and their implementation of the QU.A.L.ITY criteria.

In what concerns ***quantification***, for instance, the EU ETS Directive and the associated Monitoring and Reporting Regulation provide protocols for measuring and reporting project on-site emissions. Combined with the CCS Directive they provide a framework for the governance of geological storage site selection and operation, and for identification and measurement of leaks and reversals associated with CO_2 transport and storage. The lifecycle accounting rules of the RED II and the GHG emissions calculation methodology for the Innovation Fund could further inform the development of emissions calculation principles and the formulation of standard equations for assessing net carbon removals. The certification standards provide several examples of the functioning implementation of carbon removal assessment approaches, including a range of approaches to the consideration of market mediated indirect emissions. Other points that will need to be further considered in the development of EU certification methodologies include treatment of embodied emissions in capital goods (construction of buildings and manufacturing of equipment), assignment of emissions factors to consumed electricity, and allocation of emissions when removals can be considered a co-product of a larger system (e.g. in BECCS).

With regard to ***additionality***, there are examples of additionality principles in the RED II and of baselining approaches in the Innovation Fund, but the certification standards provide examples that are more complete in the context of assessing carbon removals. A number of existing schemes either directly reference the CDM additionality tools or have their own additionality assessment systems that can be seen as streamlined versions of CDM requirements to consider financial and regulatory additionality. There are also, however, examples of standards that allow additionality to be assessed through a performance standard in at least some cases, which can be seen as analogous to the baseline-focused additionality assessment anticipated in the proposed CRCF. There are also standards that allow the use of 'positive list' additionality, and the protocols for adding entries to positive lists may also be relevant to the development of the EU framework.

As regards ***long-term storage***, the CCS Directive provides an indication of an approach to manage long-term geological storage and of an approach to liability transfer. The existing body of legislation does not directly provide a ready-to-use and broadly applicable definition of long-term storage, but a delegated act to the ETS is anticipated that will provide additional guidance on the treatment of what it means for carbon to be permanently chemically bound in a product. The certification standards differ in their interpretation of what may be counted as ***'long-term'***, differences that are in part informed by the background of the standards. Systems that have been developed to certify carbon reductions or removals in the AFOLU sector have been forced to handle issues of impermanence and of relatively high reversal risk, and may count long-term storage in decades – systems designed to handle only geological storage or mineralisation aspire to storage that can be considered effectively permanent for practical purposes. The relative treatment and comparability of less-permanent removals approaches that may deliver storage on the order of centuries requires careful consideration.

Regarding ***sustainability**,* the Taxonomy Regulation provides examples of detailed criteria to show that activities do no significant harm to or make a substantial contribution to key sustainability objectives could inform the implementation of the neutral impact or co-benefit requirement in the proposed CRCF. In the particular case of biomass use, the RED II also contains a set of sustainability requirements for biomass used in bioenergy applications. The certification standards impose sustainability requirements through permutations that can combine no net harm principles, requirements for impact analysis, requirements for legal compliance and in several cases a focus on the sustainable development goals.

The findings documented in this review, together with additional input received from the Expert Group and with the additional information and new approaches that are continuously emerging in the developing field of carbon removals, will be used to inform the development of EU carbon removal certification methodologies. Developing methodologies will require ongoing consideration of which approaches in existing measures are most consistent with the QU.A.L.ITY principles laid down in the proposed CRCF, and further exploration of where the balance can be found that allows the co-delivery of, on the one hand, robustness and ensuring environmental integrity and, on the other, implementable and practical requirements that are not unduly burdensome.

1 Introduction and context

On 30 November 2022, the European Commission adopted a proposal for Regulation establishing a first EU-wide voluntary carbon removal certification framework (CRCF)[1] to reliably certify high-quality carbon removals. The proposed regulation aims to boost innovative carbon removal technologies and sustainable carbon farming solutions, and contribute to the EU's climate, environmental and zero-pollution goals. It should significantly improve the EU's capacity to quantify, monitor and verify carbon removals. Higher transparency will ensure trust from stakeholders and industry, and prevent greenwashing. Moving forward, the Commission, supported by experts, will develop tailored certification methodologies for carbon removal activities delivering on climate and other environmental objectives.

To ensure the transparency and credibility of the certification process, the proposal sets out rules for the independent verification of carbon removals, as well as rules to recognise certification schemes that can be used to demonstrate compliance with the EU framework. To ensure the quality and comparability of carbon removals, the proposed regulation establishes four QU.A.L.ITY criteria:

1. Quantification: Carbon removal activities need to deliver unambiguous benefits for the climate and be measured, monitored and reported accurately;
2. Additionality: Carbon removal activities need to go beyond existing practices and what is required by law;
3. Long-term storage: Certificates are linked to the duration of carbon storage and should ensure long-term storage;
4. Sustainability: Carbon removal activities must contribute to sustainability objectives such as climate change adaptation, circular economy, water and marine resources, and biodiversity.

The European Union (EU) Commission's proposal for a Carbon Removal Certification Framework (CRCF) anticipates a European Union standard for the certification of robust high quality carbon removals, implemented through certification methodologies for specific carbon removal activities.

In the specific context of industrial carbon removals, i.e. technology-based solutions developed by industry to remove carbon from the atmosphere, the EU carbon removal certification methodologies may draw on elements of existing EU legislation. For example, governance of carbon capture and storage (CCS) activities within carbon removal projects might be based on the existing requirements of the CCS Directive. Monitoring and reporting principles may draw on existing principles under the EU Emissions Trading System (ETS) and the Innovation Fund. Certification will be delivered through independent certification schemes managed by public or private organisations, certifying against the EU criteria. There are already a number of schemes in operation offering certification of carbon removals and related activities. Elements of these existing schemes can also inform the EU rules as examples of existing best practice, and some of the operators of existing certification schemes could in due course be recognised under the CRCF.

This review summarises the review of elements of existing EU legislation and of a number of existing certification schemes that might inform the development of EU certification

[1] COM (2022) 672 final: Proposal for a Regulation on an EU certification for carbon removals

methodologies for industrial carbon removals. It identifies where EU certification methodologies, particularly Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Capture (DAC) with Carbon Storage (DACCS) projects, can draw on elements of existing legislation and elements of existing schemes. It also identifies areas in which there are important differences among existing treatments and where it may be necessary to further develop certification approaches to deliver the QU.A.L.ITY criteria.

Section 2 provides a review of existing EU regulatory measures, while Section 3 offers a review of existing schemes administered by private bodies or non-EU public bodies.

Note that this review does not aim to present a fully comprehensive comparative review of the full range of private standards that are currently available globally – rather it seeks to identify content from a wide range of existing standards that is relevant to the development of EU certification methodologies. Carbon farming and storing carbon in harvested wood products are outside of the scope of this paper.

1.1 Common ideas in emissions quantification

There are certain common ideas shared by many of the regulations and standards discussed below, which it is useful to introduce in advance rather than to reiterate with each case.

1.1.1 The use of standard emission factors for combustion processes

It is common when assessing the greenhouse gases (GHG) emissions from fuel combustion processes that rather than directly monitoring the amount of CO_2 in the flue gas of an emission source, the emissions are allowed to be calculated as the product of the amount of a given fuel consumed and a standard emission factor (a quantity of CO_2 released per unit of fuel combusted), which is referred to in the Monitoring and Reporting Regulation (MRR) as a calculation-based methodology. In this way, emissions may be calculated based on 'activity data' that operators will generally already record, rather than requiring the installation of expensive flue gas monitoring equipment (referred to in the MRR as a measurement-based methodology). When a calculation methodology is permitted, it is assumed that any variations in the energy density and carbon content of a given fuel are of negligible importance compared to correctly characterising the quantity consumed.

1.1.2 The use of lifecycle inventory data

Where the scope of an emissions assessment includes the emissions 'embedded' in inputs to a process (for example the CO_2 associated with the energy required to produce chemical inputs) it is normal to allow those emissions to be based on values in an inventory of lifecycle data, rather than requiring project operators to establish the average emissions associated with the production of the actual inputs consumed at specific production facilities.

1.1.3 Emissions monitoring versus lifecycle assessment

There is a distinction between frameworks that focus on emissions sources and sinks that are strictly within the geographical boundary of a set of facilities directly associated with carbon removal[2] (e.g. a carbon capture facility, transport infrastructure and storage site) and frameworks that adopt a lifecycle assessment (LCA) approach. In an LCA approach, projects must also consider the emissions occurring outside the geographical boundaries of facilities under their control but that are associated with energy and material flows in and out of their

[2] Sometimes including transport, so that e.g., 'the roads between facility A and facility B' implicitly come within the geographical boundary.

facilities, for example due to production of energy and production of chemical inputs, or due to end-of-life (EoL) handling of waste materials. Note that even within these broad categories, there may be significant differences in the definition of the scope of emissions to be assessed. For example, an assessment that is focused on on-site sources and sinks might still include emissions associated with electricity or heat production, while different LCA can have very different approaches to ‘indirect’ emissions, or to whether default or actual emissions values, or average or marginal values, should be used for consumed inputs.

1.2 Note on ‘leakage’ and indirect emissions

The term leakage is used in the proposed CRCF Regulation with two different meanings. In the context of CO_2 transport and storage, leakage can refer to physical leakage of CO_2 from containment, such as fugitive CO_2 emissions from CO_2 pipelines or CO_2 escaping from storage reservoirs. Leakage also refers more broadly to the risk of indirect emissions changes associated with climate action, for example the risk that regulating an activity under the EU ETS will lead to that activity being shifted to countries outside the EU where the emissions are either unregulated or less strictly regulated, so that a recorded reduction in EU emissions would not be associated with the same reduction in net global emissions. In this review, the term leakage is used in both senses – it should be clear from context which sense is being used in each instance, but where it is felt it is useful to clarify we do so by referring to ‘physical leakage’ or ‘indirect emissions/leakage’. In the report, subsections headed “Indirect emissions and leakage” refer to the leakage in the second sense.

Note that the term ‘leakage emissions’ is used variously by existing standards in both of the above senses and also to describe emissions that we refer to in this report as lifecycle emissions (e.g. energy use upstream or downstream of the project facility). Similarly, some standards use the term ‘indirect’ emissions to refer to any emissions occurring away from the project facility, even though these emissions may be referred to as direct emissions within a lifecycle analysis framing. The proposed CRCF says, *“Relevant greenhouse gas emissions that should be taken into consideration include direct emissions, such as those resulting from the use of more fertilisers, fuel or energy, or indirect emissions, such as those resulting from land use change”*, and in this report we therefore refer to all emissions in the supply chain upstream or downstream of a carbon removals project (including any waste disposal emissions) as direct or as lifecycle emissions, and only refer to market-mediated emissions (such as indirect land use change emissions) as indirect.

1.3 Note on carbon and CO_2 storage

Some storage approaches (such as geological sequestration of CO_2) store carbon in the form of CO_2 molecules, while other storage approaches (such as carbonated building materials or woody biomass burial) store carbon in the form of other molecules. The amount of CO_2 storage in kilograms, consistent with the storage of a given number of kilograms of carbon atoms, may be calculated by multiplying by a factor of 44/12. In this report, we will use the terms ‘carbon storage’ and ‘carbon dioxide storage’ somewhat interchangeably – in the case that the storage of carbon in molecules other than CO_2 is nevertheless referred to as CO_2 storage, it should be taken as implicit that 1 kilogram of long-term carbon storage is equivalent to 44/12 kilograms of long-term CO_2 storage.

1.4 ‘Ex-ante’ and ‘ex-post’ certification of removals

The goal of carbon removal certification is to identify projects that reduce net atmospheric carbon dioxide concentrations, but projects differ as to whether the physical removal of CO_2 from the atmosphere happens before, during or after the main project activity. When CO_2 is removed from the atmosphere before or at the same time as a project activity is awarded certificates, the certification may be referred to as ‘ex post’. If CO_2 is removed from the atmosphere after the project activity is awarded certificates, the certification may be referred to as ‘ex ante’. For example, a direct air capture project actively removes CO_2 from the atmosphere. If this project is awarded carbon removals certificates at the end of each project period based on the verified amount of CO_2 removed, that is ex post certification. If instead the project was awarded carbon removal certificates at the beginning of a project period based on the expected CO_2 that would be removed in that period under normal operation, that would be ex ante certification.

For projects such as direct air capture where CO_2 removal can be delivered on a short timescale, it is generally accepted that ex post certification is appropriate. For some project types, however, ex post certification might introduce a significant gap between the point at which capital and operational costs occur and the point at which carbon removal certificates could be claimed. For example, enhanced rock weathering projects may deliver gradual CO_2 removal from the atmosphere for one or more decades after the point at which rock powder is applied to the field. Similarly but in a non-industrial context, afforestation projects may continue to remove CO_2 from the atmosphere for decades after trees are planted. It is possible to model the CO_2 removal expected from an enhanced weathering project at the point that rock powder is applied, and carbon removal certificates could be awarded ex ante based on that modelling.

In the case of projects based on utilisation of biomass resources, the timing of physical carbon removals may be dependent on the model of feedstock supply and how the carbon in standing biomass is treated. For example, if a BECCS project harvests biomass from a stand of trees that has been in a state of equilibrium carbon stock for many years, one view would be that the carbon removal from the atmosphere had already happened many years previously and that any certification would therefore be ex post. An alternative conception would be that the carbon removal associated with the project only actually happens as the trees grow back after harvesting. On that understanding, awarding certificates at the same time that CO_2 is stored would be a form of ex ante certification. The interpretation of whether biomass-based removals are delivered ex ante or ex post is related to issues of carbon payback periods for biomass harvesting, and different conclusions might be drawn depending on the specific biomass feedstocks used by each project.

The proposed CRCF does not explicitly limit certification to an ex post basis, but it is noted that allowing ex ante certification may raise additional issues in terms of assessing uncertainty, monitoring and understanding reversal risks.

2 Assessment of relevant methodologies from EU regulatory framework

Several EU legislation and policies include methodological elements of relevance for the industrial carbon removal framework. In this section the EU legislation and policies of relevance are reviewed regarding their practical relevance for the certification of net carbon removals and their support for the implementation of the QU.A.L.ITY criteria. The aim is to obtain coherence and consistency between existing regulation and the carbon removal methodology, and to use common definitions and language.

2.1 EU ETS Directive

The EU ETS Directive 2003/87/EC ("the EU ETS"[3]) sets rules for the award and surrender of allowances in relation to GHG emissions from activities listed in Annex I of the Directive. Regulated activities include various specified industrial activities and emissions from any combustion installation with a rated thermal input exceeding 20 MW, excepting facilities combusting hazardous or municipal waste. Emissions from the combustion of biomass are zero rated under the EU ETS and do not create an obligation to surrender allowances (plants with 100% biomass combustion are out of scope for the ETS), and therefore there is currently no benefit under the EU ETS to capturing CO_2 emissions from the burning of biomass.

Emissions from GHG capture at regulated installations and from transport and storage of that CO_2 are also regulated under Annex I. There is no obligation to surrender allowances in the case of CO_2 verified as captured and transported for permanent storage to a facility permitted under the CCS Directive, nor in the case of carbon captured and utilised in such a way to become permanently chemically bound in a product, (if that carbon will not enter the atmosphere under normal use, including through any normal activity taking place after the EoL of the product, Articles 12(3a) and 12(3b)). As such, the EU ETS ensures that emissions associated with CO_2 leakage during storage or transport are regulated in a closed system.

The Directive sets emissions monitoring rules through the Monitoring and Reporting Regulation (MRR), as well as requirements on verification of emissions data.

Relevance for the CRCF:

Quantification: The EU ETS regulates direct, on-site emissions sources and sinks only. It does not consider lifecycle emissions, nor does it consider indirect emissions. The EU ETS recognises the issue of indirect emissions due to emissions leakage[4] but does not provide mechanisms to quantify it. Free allowances are used to reduce the risk of leakage, and the Directive calls upon Member States to use revenues from the auction of allowances to reduce the risk of leakage. The detailed rules for monitoring of on-site sources and sinks are provided in the MRR (see Section 2.2). In general, carbon removal activities excepting those that involve CCS are not currently regulated under the EU ETS. ETS would not regulate, for instance, land and biomass-based carbon removals or direct air capture[5], or small emitters (e.g., combustion activities < 20 MW). The EU ETS explicitly includes transport of CO_2 and permanent geological storage as regulated activities under Annex I, i.e., all measurement, verification and reporting (MRV) requirements, as well as the obligation to surrender allowances for all emissions, apply.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02003L0087-20230605

[4] Note that any physical leaks of CO_2 due to fugitive emissions/venting would be within scope of the ETS.

[5] Note that the EU ETS does allow revenues from the auction of allowances to be used to support research and development in direct air capture.

Long-term storage: Under the EU ETS, no obligation to surrender allowances will arise when CO_2 is captured and is either transported for permanent geological storage or (once rules for permanently chemically bound carbon have been agreed) is utilised and becomes permanently chemically bound. Permanent geological storage is regulated by the CCS Directive[6]. For carbon to be treated as permanently chemically bound in a product it must 'not enter the atmosphere during normal use', including after the EoL of the product. The EU ETS calls for a delegated act to further define requirements for carbon to be considered chemically bound, but it is our understanding that no such delegated act has been adopted to date.

Liability: Companies subject to mandatory participation in the EU ETS are responsible for fulfilling the ETS obligations, i.e., reporting obligations and allowance surrender under the EU ETS. In the context of CCS, the operator of an installation, transport network or storage site is responsible for compliance. In the case of carbon chemically bound in products, the ETS anticipates the adoption of delegated acts to further detail the requirements. Liability for CO_2 storage locations may, however, be transferred to the state following site closure in line with the rules of the CCS Directive.

2.2 Monitoring and Reporting Regulation

The Monitoring and Reporting Regulation 2018/2066[7], henceforth MRR, sets out rules for the monitoring and reporting of GHG emissions from activities listed in Annex I of the EU ETS and of activity data from stationary installations. Among other things, it defines the boundaries for emissions reporting for stationary installations and regulates accounting of transferred CO_2. The MRR includes maximum permitted levels of uncertainty in measurement of activity data for each source or sink based on four tiers, with higher tiers requiring less uncertainty in measurement of activity data. It also sets requirements on the implementation of data flow activities for monitoring and reporting.

Relevance for the CRCF:

Quantification: The MRR provides detailed regulation on the quantification of direct emissions from stationary installations regulated under the EU ETS (see in particular Annex II and IV), including a definition of boundaries and uncertainty requirements for reporting. This is particularly relevant for transport and storage of CO_2, as regulated activities under the EU ETS.

The MRR defines two types of source monitoring methodologies (as noted above in the introduction) – 'calculation based' and 'monitoring based'. Under a calculation-based methodology, emissions are to be calculated as the product of the quantity of fuel consumed (in terajoules expressed on a lower heating value basis[8], this quantity is referred to as activity data), an emission factor for that fuel (in tonnes of CO_2 per terajoule combusted[9]) and an oxidation factor for the combustion process (the tier 1 oxidation factor is set as 1). Activity data must be reported based on measurement systems under the operator's control that deliver results within the permitted uncertainty thresholds for the tier relevant to the particular source and that are calibrated at least annually, unless this is not technically feasible or would incur unreasonable cost, in which case activity data may be based on data from previous years correlated to output in the reporting period or to relevant data in financial

[6] The CCS Directive allows transfer of liability for stored CO_2 only when *"all available evidence indicates that the stored CO_2 will be completely and permanently contained"* but does not provide an explicit definition of how permanence should be assessed.

[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018R2066-20220828

[8] 'Lower heating value' is also referred to as net calorific value, and refers to the quantity of energy released by combusting a given quantity of fuel, excluding the energy required to vaporise any water in the combustion products.

[9] Which is equivalent to the value in grams of CO_2 per megajoule combusted.

statements. Measurement based methodologies are to be used for emissions of nitrous oxide, and for the assessment of quantities of CO_2 transferred out of the installation with a view to long-term geological storage or to produce precipitated calcium carbonate, and may be used by operators to assess other sources where the quality of the measurement data meets the requirements of the relevant tier. The MRR includes protocols to handle gaps in measurement data availability, requires measurement data to be corroborated with relevant calculations, and sets principles for quality assurance: all relevant measuring equipment must be calibrated, adjusted and checked regularly, and should apply quality assurance to continuous measurement systems consistent with the requirements of EN 14181.

The MRR defines relaxed rules for reporting of activity data for biomass source streams providing the source stream is 100% biomass and meets the sustainability requirements of the Renewable Energy Directive, including the requirements on minimum reportable GHG emissions reductions based on the RED II LCA rules (70% for electricity and heating from installations starting operation between 2021 and 2025, and 80% for installation starting operation from 2026 onwards, but no minimum for installations already in operation before 2021). An emission factor of zero is set for biomass combustion emissions.

Boundaries: The MRR defines the boundaries for reporting of direct emissions for installations under the EU ETS. It specifies that operators of regulated facilities must consider emission sources from: boilers, burners, turbines, heaters, furnaces, incinerators, calciners, kilns, ovens, dryers, engines, fuel cells, chemical looping combustion units, flares, thermal or catalytic post-combustion units, and scrubbers (process emissions) and any other equipment or machinery that uses fuel (excepting for transportation purposes). Additional guidance is provided specifying the scope of monitoring for specific activities.

The MRR does not consider upstream emissions (e.g., from electricity or heat use or for life cycle emissions) or indirect emissions.

2.3 CCS Directive

The CCS Directive 2009/31/EC[10] provides detailed rules for the environmentally safe geological storage of CO_2. The Directive has legal application within the territory of EU and EEA Member States, and within their exclusive economic zones and on their continental shelves within the meaning of the United Nations Convention on the Law of the Sea, but the principles of the Directive could be applied to storage in other jurisdictions. The CCS Directive applies only to geological storage of CO_2, meaning storage by injection of CO_2 into geological formations – it has no direct applicability to other forms of long-term carbon storage.

The CCS Directive outlines rules for selection, operation and monitoring of storage sites. The rules for selection of storage sites are intended to guarantee that there should be no significant risk of leakage from that site and that there should be no significant environmental or health risk associated with the use of that site for CO_2 storage. The requirements of the Directive are supported through four guidance documents[11] relating to:

1. CO_2 Storage Life Cycle Risk Management Framework;
2. Characterisation of the Storage Complex, CO_2 Stream Composition, Monitoring and Corrective Measures;
3. Criteria for Transfer of Responsibility to the Competent Authority; and,
4. Financial Security (Art. 19) and Financial Mechanism (Art. 20).

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02009L0031-20181224

[11] https://climate.ec.europa.eu/eu-action/carbon-capture-use-and-storage/implementation-ccs-directive_en#documentation [Note that under a different contract for DG CLIMA, these Guidance Documents are currently being revised by DNV, following extensive stakeholder consultation and review through 2023]

Article 16 of the Directive describes measures to be taken in the event of CO_2 leakage or of significant irregularities. Operators must be required to immediately notify competent authorities and take the necessary corrective measures (as specified in a corrective measures plan which is approved at the point of issuance of a storage permit). In the result of leakage, the competent authority in respect of the EU ETS must also be notified so that allowances may be surrendered under the EU ETS to compensate for the leakage. Further guidance on corrective measures is provided in Guidance Document 2 on the implementation of the CCS Directive[12].

The Directive also sets conditions for closure of a storage site and for post-closure obligations on the operator (Article 17). The post-closure plan must be submitted to the competent authority as preliminary with the application for a storage permit and must be finalised after re-submission prior to site closure. Article 18 allows for all legal responsibility for a storage site to be transferred to a competent authority following site closure, subject to certain conditions:

- all available evidence indicates that the stored CO_2 will be completely and permanently contained;
- a period not normally shorter than 20 years[13] has passed since the closure of the site;
- a financial transfer from the operator to the competent authority consistent with the expected cost of post-transfer obligations, including ongoing monitoring for 30 years; and,
- the site has been sealed and injection equipment removed.

Note that the CCS Directive places legal obligations only on the storage operator, no direct legal responsibility is created for the operator that captured the CO_2, even if that operator claimed the benefit of CO_2 storage in terms of contribution to regulatory compliance (e.g., by avoiding the requirement to surrender allowances under EU ETS) or generation of carbon removal certificates under a voluntary scheme.

Relevance for the CRCF:

Long-term storage: The CCS Directive contains relevant aspects on the operation of a storage site, including selection of storage sites, conditions for the applications for storage permits, CO_2 stream acceptance criteria, monitoring and reporting rules for storage sites, leakage measurement and countermeasures as well as on closure of a site, post-closure obligations and transfer of responsibility after closure. The CCS Directive also defines the necessary reactions in case of physical CO_2 leakage, including reporting of emissions and taking of countermeasures.

Liability: The CCS Directive puts liability for emissions from a storage site (including leakage) with the operator of the site. That includes liability for reporting of emissions under the EU ETS and compliance with allowance obligations, as well as liability for remedial measures in the event of leakage. The liability can be transferred to the competent authority if all requirements on the safety and impermeability of the storage site are met, at the earliest, 20 years after closure of a storage site. The transfer of responsibility includes a financial transfer for expected costs for monitoring and other post-transfer obligations for at least another 30 years.

The CCS Directive also creates a requirement for Member States to require proof from operators, before they are awarded storage permits, that all obligations associated with the CCS permit, including closure and post-closure requirements, can be met. This should be provided by way of financial security or other equivalent measure (Article 19). This is intended to ensure that financial obligations can still be met in the event of, for example,

[12] https://climate.ec.europa.eu/system/files/2016-11/gd2_en.pdf

[13] The competent authority is permitted to set a shorter period if it is convinced that, at a point earlier than 20 years after closure, the stored CO_2 will be completely and permanently contained.

bankruptcy of the operator. CCS Directive Guidance Document 4[14] provides a more detailed discussion of which sorts of instrument would be appropriate.

2.4 Renewable Energy Directive

The revised Renewable Energy Directive 2018/2001 (RED II)[15] sets targets for the use of renewable energy in the overall EU energy supply, and sub-targets for renewable energy in sectors including transport, heating and cooling and industry. The RED II (1) sets rules that enable the calculation of the share of energy from renewable sources; (2) creates a framework for support schemes for renewable energy; (3) sets the basis for the system of Guarantees of Origin (GoO) for renewable energy[16]; and (4) sets rules relating to the sustainability of the biomass used. Note that the Renewable Energy Directive is being revised as part of the Fit for 55 process, and the RED II will be revised to “RED III”. The discussion below is based on the text of RED II, but is generally also applicable to the reviewed RED III.

Relevance for the CRCF:

Quantification: The RED II sets calculation rules to assess the lifecycle GHG intensity of biomass energy, recycled carbon fuels (RCFs)[17] and of renewable fuels of non-biological origin (RFNBOs). The rules for RFNBOs include systems for identifying electricity use as additional and renewable, which may be relevant to the consideration and/or management of indirect emissions associated with electricity consumed for DAC. The rules for assessing the renewability[18] and lifecycle GHG emissions[19] of RFNBOs include provisions for when electricity used in RFNBO production may be treated as renewable in both the case of a direct connection to a renewable power facility and of a grid connection.

Sustainability: The RED II sets out rules for assessing the sustainability of biomass used for bioenergy applications. The RED II also includes definitions of various biomass-relevant terms.

The sustainability criteria for biomass given in the RED II:

- Set maximum thresholds on the reportable GHG emissions intensity of bioenergy[20] (Article 29(10)), after accounting for land use change emissions, if the land on which the biomass is produced has changed status;
- Prohibit the use of biomass taken from land that was considered to have high biodiversity status on or after January 2008;
- Prohibit the use of biomass from land that was considered to have a high carbon stock status in January 2008 if that status has changed;
- Prohibit the use of agricultural biomass from land that was peatland in January 2008 where cultivation or harvesting of that biomass involves draining the soil;
- Require that forest biomass shall only be used for bioenergy if it was produced under laws or voluntarily adopted standards that enforce principles of sustainable forestry,

[14] https://climate.ec.europa.eu/system/files/2016-11/gd4_en.pdf

[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20220607

[16] Guarantee of Origin (GO or GoO) is an energy certificate defined in article 19 of the European Directive 2018/2001/EC (previously in article 15 of European Directive 2009/28/EC).

[17] Through implementing acts.

[18] https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj

[19] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2023)1086

[20] These thresholds are framed as minimum GHG emissions savings by including defined fossil fuel comparator values.

including considering the maintenance of soil quality and biodiversity with a view to minimising negative impacts;

- Require that forest biomass shall only be used for bioenergy if it is produced in a country that has submitted a nationally determined contribution to the UNFCCC under the Paris Agreement that includes emissions and removals from AFOLU and has laws in place applicable to the area of harvest such that carbon sinks are maintained and that LULUCF-sector emissions do not exceed removals, or if it is produced within a management system applicable to the harvest area that ensures that carbon stocks and sinks are maintained or strengthened.

The RED II also sets requirements on the thermal efficiency of biomass combustion plants with a thermal input of 50 MW or greater. However, these are considered to be met automatically if the facility applies carbon capture and storage.

2.5 Sustainable Finance Taxonomy

The Taxonomy Regulation (2020/852) establishes a framework for the identification of sustainable activities that a) make a substantial contribution in at least one sustainability objective and that do no significant harm (DNSH) to other objectives. The sustainability objectives are:

- climate change mitigation;
- climate change adaptation;
- the sustainable use and protection of water and marine resources;
- the transition to a circular economy;
- pollution prevention and control; and,
- the protection and restoration of biodiversity and ecosystems.

The proposal for a CRCF regulation requires that activities “shall have a neutral impact on or generate co-benefits for” these six objectives.

The Taxonomy Regulation provides guidance as to how a substantial contribution or significant harm to these environmental objectives shall be defined. It is supported by two delegated acts (one relating to the climate objectives[21] and one relating to the other environmental objectives[22]) that contain technical screening criteria for specific economic activities for substantial contributions to relevant objectives, and to show that activities do no significant harm to the other objectives. Technical screening criteria are developed with the support of the EU Platform on Sustainable Finance. The process of developing the Taxonomy is ongoing, and not all economic activities were allocated technical screening criteria in the first iterations of the Taxonomy process.

Relevance for the CRCF:

Sustainability: The Climate Change Mitigation and Adaptation Delegated Act includes technical screening criteria for the transport and storage of CO_2 (activities 5.11 and 5.12) and for research, development and innovation (RDI) relating to direct air capture of CO_2. There are no technical screening criteria for commercial scale DAC (activity 9.2), as this activity is not considered mature at commercial scale. However, the RDI scale criteria may still be relevant to commercial applications. It also contains technical screening criteria for other potentially relevant activities including forestry, restoration of wetlands, manufacture of plastics, manufacture of biogas and biofuels, landfill gas capture and utilisation, manufacture of cement, and construction of new buildings.

[21] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32021R2139

[22] https://finance.ec.europa.eu/system/files/2023-06/taxonomy-regulation-delegated-act-2022-environmental_en_0.pdf

The delegated acts include ‘generic’ DNSH criteria for the five non-climate mitigation objectives, as well as activity-specific DNSH criteria. These DNSH criteria should inform the implementation of Article 7(1) of the CRCF

2.6 Innovation Fund

The EU ETS Innovation Fund provides grants to innovative low carbon technologies using revenue from the sale of ETS allowances. We have reviewed version 2.0 of the Innovation Fund Methodology for GHG Emission Avoidance Calculation, dated November 2022[23]. It allows applications for support for a broad range of projects, divided into three eligibility categories: Energy Intensive Industries (EII); Renewable Energy (RE); and Energy Storage (ES). Projects make applications to bid for funds, and the successful bids are rated based on a consideration of innovation, GHG avoidance potential, project maturity, replicability and cost efficiency. Projects in the EII and RE eligibility categories may include elements of carbon capture and storage (CCS) or carbon capture and utilisation (CCU). Projects identified as delivering carbon removals under the Innovation Fund GHG calculation methodology are given additional points in project scoring.

Relevance for the CRCF:

Quantification: The GHG savings for Innovation Fund projects are calculated as the difference between the emissions in the project scenario and the emissions in a reference scenario. The reference scenario plays a similar role in the calculation methodology to baseline scenarios in GHG reduction/removal certification methodologies. The Innovation Fund uses a mix of standardised baselines and project-specific baselines depending on the products being produced and details of the project. For EII projects the reference emissions may be based on an EU ETS benchmark value, but could also be based on the emissions of a facility prior to modification or on some other basis proposed by the applicant. Standard reference values for electricity or heat supplied are pre-defined for most RE and ES projects.

The GHG calculation for the project scenario and for non-standardised parts of the reference scenario in the Innovation Fund uses a form of attributional lifecycle analysis, but differs in scope from some regulatory lifecycle analysis (for example differing from the lifecycle analysis rules in the RED II) because the scope of the analysis is adjusted for consistency with the EU ETS, and to make the analysis forward-looking. For example, no upstream emissions are to be counted from the supply of fossil fuels consumed in a project scenario, and grid electricity used as a project input is always given an emission factor of zero (reflecting the expectation that the EU electricity grid will be fully decarbonised on a timescale relevant to the scale up of these innovative technologies). Biomass combustion CO_2 emissions are treated as zero throughout the Innovation Fund, but emissions of non-CO_2 gases from combustion (methane, nitrous oxide) are included in scope. Biomass production emissions are to be assessed and included based on the RED II LCA rules.

Where a project reports negative emissions in the project scenario, it may qualify as a carbon removal project. Negative emissions terms in the Innovation Fund calculation can represent:

- Carbon capture and storage;
- Carbon capture and utilisation;[24]
- Storage of biogenic carbon in long-lived products;
- Supply of additional non-principal products;
- Timed electricity use to reduce pressure on the grid; and,

[23] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/innovfund/guidance/ghg-emission-avoidance-methodology_innovfund_en.pdf

[24] Note that if the carbon in a CCU product is released at end of life this must be counted as an emission and will cancel out the negative term for the initial utilisation.

- Avoided emissions from the use of rigid inputs that would otherwise be disposed of in a way that leads to CO_2 emissions.

In order to qualify as achieving net carbon removals, a project must have a negative emissions score in the project scenario excluding any negative emissions associated with non-principal products[25] or with timed operation. That means that the magnitude of the summed negative emission terms, excluding non-principal product credits and timed operation, must be greater than the magnitude of the summed positive emission terms for the project. Net carbon removals projects under the Innovation Fund definition will therefore involve at least one of CCS, CCU with carbon stored in long-lived products, storage of biogenic carbon in long-lived products, or avoidance in emissions associated with alternative disposal of rigid inputs. DACCS projects should always qualify as net carbon removals projects under the Innovation Fund methodology[26], however BECCS projects will only qualify if the amount of CO_2 captured is greater than the CO_2 emissions associated with biomass production and project operation (which may not be the case if, for example, only a modest percentage of the total CO_2 emitted is captured).

The negative emission term (credit) given for CCS is calculated as the amount of carbon injected for permanent storage, minus the sum of any emissions associated with capture, transport and storage, and a CCS credit under the Innovation Fund may only be awarded where the storage site is permitted under the CCS Directive. The scope for crediting for captured carbon and biogenic carbon in long-lived products is relatively broad. If the carbon is chemically bound in a product that is expected to have a useful lifetime of at least 50 years, then the project may claim a CO_2 utilisation credit equivalent to half of the quantity of carbon in the product[27], minus any emissions associated with capture and utilisation. If the applicant can show that at least 90% of the carbon in the material produced is likely to be recycled, then the project may claim a CO_2 utilisation credit for the whole quantity of carbon in the material, minus any emissions associated with capture and utilisation.[28] There is no specific requirement on the types of long-lived or recycled products for which these credits can be claimed, but applicants must satisfy the project evaluators that their claims are justified, e.g. the calculation methodology for carbon in long-lived products states that, “It is the responsibility of the applicant to convincingly demonstrate to the evaluators that it is reasonable to assume that the carbon will normally remain incorporated for at least 50 years”.

MRV: Beneficiaries have to demonstrate, at the operation stage, that GHG emission avoidance follow the same assumptions made during the application for funding. As such, beneficiaries shall obtain, record, compile, analyse and document the data, including assumptions, references, activity data and calculation factors in a transparent manner that enables the checking of performance achieved during the operation of the project.

The Innovation Fund requires that, at the reporting stage, measurements shall be conducted with calibrated measurement equipment according to industry standards and in line with relevant EU ETS MRV requirements. Each parameter monitored shall be accompanied with the following information:

- Source of the data
- Measurement methods and procedures

[25] Emissions avoided by producing non-principal products are, however, counted in assessing the ‘adjusted relative emissions avoidance’ score for a net carbon removals project, which is used to determine the number of bonus points given.

[26] If the amount of CO_2 captured was not greater than the operational CO_2 emissions, then the project would not be eligible to apply to the Innovation Fund as it would not be able to report any absolute CO_2 saving.

[27] This is implemented through a 50% reduction in the end-of-life emissions that must be reported, or in the case of biogenic carbon an emission credit equivalent to 50% of the carbon in the product.

[28] This is implemented through a 100% reduction in the end-of-life emissions that must be reported, or in the case of biogenic carbon an emission credit equivalent to 50% (sic) of the carbon in the product.

- Monitoring frequency
- QA/QC Procedures
- Responsibility for collection and archiving

Specifically for CCS projects, the parameters that, at minimum, shall be monitored throughout the project and be part of the project's monitoring and reporting plan to be submitted include:

- Amount of CO_2 transferred to the capture installation;
- Distance of each one-way trip ("L") travelled by road modals;
- Amount of CO_2 transported in each one-way trip by road modals;
- Distance of each one-way trip travelled by rail;
- Amount of CO_2 transported in each one-way trip by rail;
- Distance of each one-way trip travelled by maritime modals; and,
- Amount of CO_2 transported in each one-way trip by maritime modals.

For the parameters for monitoring corresponding to the capture of CO_2, transportation via pipeline and injection that will occur in the project scenario, Articles 40 to 46 and Article 49 and Annex IV, Sections 21, 22 and 23 from MRR shall be adopted.

2.7 Summary of relevant elements

Aspect	Relevant policies	Elements that could be relevant
Quantification	EU ETS Directive	Principles for on-site emission measurement and accounting.
		It will be necessary to determine whether (and, if so, when) emissions regulated under the ETS must also be accounted as project emissions for certified carbon removal projects.
		Leakage from CO_2 transport or storage sites is regulated, i.e., emissions need to be measured, verified and reported and an allowances obligation exists for those emissions.
	MRR	Detailed emissions monitoring rules applicable to on-site emissions. Provides guidance for data uncertainty assessment and for allowable uncertainty.
	CCS Directive	Rules determining eligible sites for geological CO_2 sequestration and for the robust implementation of CO_2 storage at those sites.
		Counter measures for leakage and reporting of emissions
	RED II (and associated delegated acts)	Lifecycle analysis rules for bioenergy, RFNBOs and RCFs. The rules for determining the GHG intensity of electricity used as a process input for RFNBOs may be appropriate for application to electricity used in DAC. Indicative values for indirect land use change emissions from biomass production.
	Innovation Fund	GHG emissions calculation rules for Innovation Fund projects, including carbon removals projects. Standard equations for assessment of GHG benefits from CCS and CCU projects. Treatment of carbon storage in long-term products.
		Innovation Fund provides a potentially relevant example of an intersection between LCA principles and ETS accounting principles (e.g. by treating upstream emissions from fossil fuel production as out of scope in the GHG calculations).
	Taxonomy Regulation	Reference to the product environmental footprint approach and relevant ISO standards for emissions assessment of DAC pilots.
Boundaries	MRR	Boundaries for stationary installation physical emissions assessment.
	RED II	Boundaries for lifecycle analysis of bioenergy, RCFs and RFNBOs.
	Innovation Fund	Boundaries for the GHG emissions calculation.
Additionality and baselining	RED II (Delegated Act on RFNBOs; Implementing	Rules for identifying electricity as additional and renewable.
		Rules for identifying agricultural production as additional.

Aspect	Relevant policies	Elements that could be relevant
	Regulation on low ILUC-risk)	
	EU ETS	In some cases, EU ETS benchmark values may be relevant to setting performance standards for baselining, analogously to their use under the Innovation Fund.
Long-term storage	EU ETS Directive	Article 12 defines 'permanently chemically bound'. If a delegated act is forthcoming on carbon permanently chemically bound in products, this should inform CRCF Regulation treatment of long-term storage of carbon in products.
	CCS Directive	Selection of storage sites, conditions for application of storage permits, CO_2 stream acceptance criteria, closure of site, transfer of responsibility.
Liability	EU ETS Directive	Rules for imposing liability for physical leakage from transport or storage sites on the operator.
	CCS Directive	Operator is liable for emissions (including leakage), until transfer to authority, regulates transfer of responsibility after closure of storage site.
Sustainability	RED II	Sustainability criteria for biomass use for bioenergy.
	Taxonomy Regulation	Technical screening criteria for sustainability for CO_2 transport and storage, DAC and various other potentially relevant activities, as well as generic criteria for doing no significant harm to sustainability objectives.
MRV	MRR	Requirements for on-site emissions MRV.
	RED II	Rules for the use of voluntary schemes to verify lifecycle emissions and sustainability claims, and for mass balance chain of custody management.
	Innovation Fund	Rules for monitoring of GHG savings delivered in operational phase for beneficiaries of IF grants are relevant to monitoring of carbon removals projects. Includes specific monitoring requirements for CCS projects.

3 Assessment of relevant methodologies from private standards and non-EU public frameworks

Besides existing regulations, private standards and initiatives that focus on the development of methodologies for the quantification of industrial carbon removals or reductions, or the certification of such removals or reductions, could also inform the development of the EU certification methodologies. Approaches to certify carbon emissions reductions have been treated as relevant because the challenges present in certifying reductions are often identical or analogous to the challenges in certifying removals.

As such, in this Section, we summarise the highlights of the review of selected generic and sector-specify initiatives and standards, focusing on identifying useful elements that could help securing the high-quality of the carbon removals, which could be reflected in the Commission approach. The list of initiatives to be considered was developed based on discussion with the Commission, and further informed by the results of the survey of the Expert Group (see Box 3.1 below). The set of initiatives considered provides a broad coverage of relevant work, but we recognise that it is not fully comprehensive and that other standards exist (see also section 3.14). All of the initiatives that have been reviewed were considered to be potentially relevant, but the inclusion or exclusion of any specific standard is not intended to imply any judgment as to the relative importance or relevance of that standard compared to any other. Similarly, the exclusion of any initiative from the review should not be taken to imply that that standard will not be considered at other stages of the process of development of EU certification methodologies for carbon removals. The review in this section considers the text of the standards and this review does not attempt to more broadly assess the efficacy or robustness with which those textual requirements have been implemented.

The elements of relevance for the CRCF are presented by standard and by criteria. For the purpose of this review, the heading "Quantification", comprises considerations about boundaries, and indirect emissions; "Additionality" and "Baseline" are clustered under the same heading; and any aspects related to liability identified in the standards are presented under the heading "Long-term storage".

The assessment has been conducted predominately through literature review. This has been complemented with interviews with representatives from selected initiatives involved in either the development or the operationalisation of carbon removals / CCS specific standards. This consultation allowed us to get their views on the strengths of their standards and areas in which standards depart from the QU.A.L.ITY framework. To get an in-depth understanding on the factors leading to the success of initiatives, key bottlenecks, and lessons learned a survey was circulated among experts and wider community for feedback on their experience with such methodologies from the perspective of both the user and developers.

Box 3.1 Survey responses

Supplementary to the literature research and interviews, an open survey has been circulated by the Commission on carbon removal methodologies. The survey was open between mid-August and mid-September 2023. It was an open consultation allowing everyone to participate, with the intention to receive further insights from project developers, methodology developers, users of methodologies and other actors involved in the certification of negative emissions. Survey results have been incorporated into the highlights of the desktop research for the various methodologies, private standards and non-EU public frameworks.

In total, 74 submissions were received in response to the survey, of which 23 respondents stated to be developers of methodologies or standards, five stated to be involved in the certification process, and 35 stated to be economic operators carrying out an industrial carbon removal or being an association representing those operators. Only two of the respondents stated to be users of certificates.

There were five responses specifically covering BECCS and DACCS methodologies (5 on BECCS, 3 on DACCS). Enhanced rock weathering (6), biochar (10) and long-lasting carbon storage in construction (15) and non-construction materials (6) were addressed in around half of the responses. 29 of the respondents said to either cover more than just one category of projects or to address other specific topics related to the certification of carbon removals.

Overall, 19 of the respondents describe methodologies that are either based directly on the Puro Standard, the CCS+ Standard, the Gold Standard or the VERRA standards, or mention them as highly relevant.

Other relevant literature identified through the surveys and that were not part of the scope of this work are listed in Section 3.14, and could be investigated in future work.

3.1 Clean Development Mechanism

The Clean Development Mechanism (CDM) is a market-based approach to support GHG reduction projects under the 1997 Kyoto Protocol. The primary goal of the CDM is to encourage developed countries to invest in emission reduction projects in developing nations. By doing so, developed countries can earn Certified Emission Reductions (CERs) or carbon credits. These credits represent the verified reduction in GHG emissions resulting from the implemented projects and may be offset by the developed countries against their Kyoto obligations, thus allowing developed countries to reduce the cost of meeting their Kyoto targets.

The CDM process involves several key steps. Firstly, a project developer from a developing country identifies a project that would lead to measurable GHG emission reductions. This project is then subjected to a validation process to ensure its eligibility and environmental integrity.

During the project's implementation, regular monitoring and reporting of emissions reductions take place. An independent third party verifies the emission reductions achieved by comparing measured project emissions with a baseline scenario that represents the emissions that would have occurred without the project. Upon successful verification, the project developer is issued CERs.

For land use, land-use change and forestry activities, the Kyoto Protocol stablishes a different unit to measure net removals. These are the Removals Units (RMU) (Art. 3.3, 3.4

Kyoto protocol), and can be traded to offset emissions in the mandatory and voluntary markets.

The CDM has considered the development of CCS methodologies for several years[29] and still does not have a bespoke CCS methodology document. The list of issues that should be resolved prior to enabling such projects under the CDM scheme has been identified as[30]:

- non-permanence, including long-term permanence[31]
- measuring, reporting and verification
- environmental impacts
- project activity boundaries
- international law
- liability
- the potential for perverse outcomes
- safety; and
- insurance coverage and compensation for damages caused due to seepage or leakage.

Since 2011 CCS projects have been eligible to be submitted under the CDM based on requirements listed in an Annex to document FCCC/KP/CMP/2011/10/Add.2, relying on standard CDM modalities '*mutatis mutandis*'[32].

3.1.1 Quantification

Emissions associated with CCS projects and baselines must be assessed in accordance with approved methodologies, however, there has not yet been a successful CCS project under CDM, and in order to be approved a methodology would need to be proposed and then applied to a first test project. FCCC/KP/CMP/2011/10/Add.2 states that the boundary for a CCS project should include (where applicable):

- The installation where the carbon dioxide is captured;
- Any treatment facilities;
- Transportation equipment, including pipelines and booster stations along a pipeline, or offloading facilities in the case of transportation by ship, rail or road tanker;
- Any reception facilities or holding tanks at the injection site; and,
- The injection facility;

Subsurface components, including the geological storage site and all potential sources of seepage[33], as determined during the characterization and selection of the geological storage site.

For forestry projects, Annex I of the Convention provides guidance on the estimation and reporting of emissions and removals for LULUCF activities (forest land, cropland, grassland, wetlands, settlements, harvested wood products, including:

- choice of method
- emission factor
- activity data: total area
- calculation steps for TIER 1: net carbon stock change in dead organic matter per area, net carbon stock change in soils per area

[29] https://cdm.unfccc.int/about/ccs/index.html

[30] https://globalccsinstitute.com/archive/hub/publications/25786/manual-developing-ccs-projects-under-cdm.pdf

[31] This list is from a negotiated text (UNFCCC, decision 2/CMP.5, 2009), and it is not fully explicit how the terms 'non-permanence' and 'long-term permanence' are to be understood here.

[32] https://unfccc.int/resource/docs/2011/cmp7/eng/10a02.pdf

[33] Note that the term 'leakage' has a specific meaning in CDM and therefore CDM refers to CO_2 leaks from storage reservoirs as seepage instead.

- uncertainty assessment.

Emissions outside of the project boundaries (referred to as leakage emissions) are to be considered to the extent that they are ‘measurable and attributable’ – we understand that in practice this means that lifecycle supply chain emissions are to be assessed but indirect emissions are not.

3.1.2 Additionality and baselining

It is a central principle of the CDM that only projects that can be considered ‘additional’ should be credited, meaning only projects that would not have happened in the absence of the CDM should be awarded CDM credits. This is important, as in the absence of additionality rules developed countries would be able to take credit for emissions reductions in developing countries that would have happened anyway, undermining the integrity of the Kyoto system of GHG targets. The CDM provides both a ‘Tool for the demonstration and assessment of additionality’, and a ‘Combined tool to identify the baseline scenario and demonstrate additionality’. The former can be used if the project proponent proposes their own baselining methodology or a project-specific CDM baselining methodology.

The process for assessing additionality is illustrated in Figure 3.1; a simplified assessment applies for projects that can be characterised as ‘first-of-its-kind’.

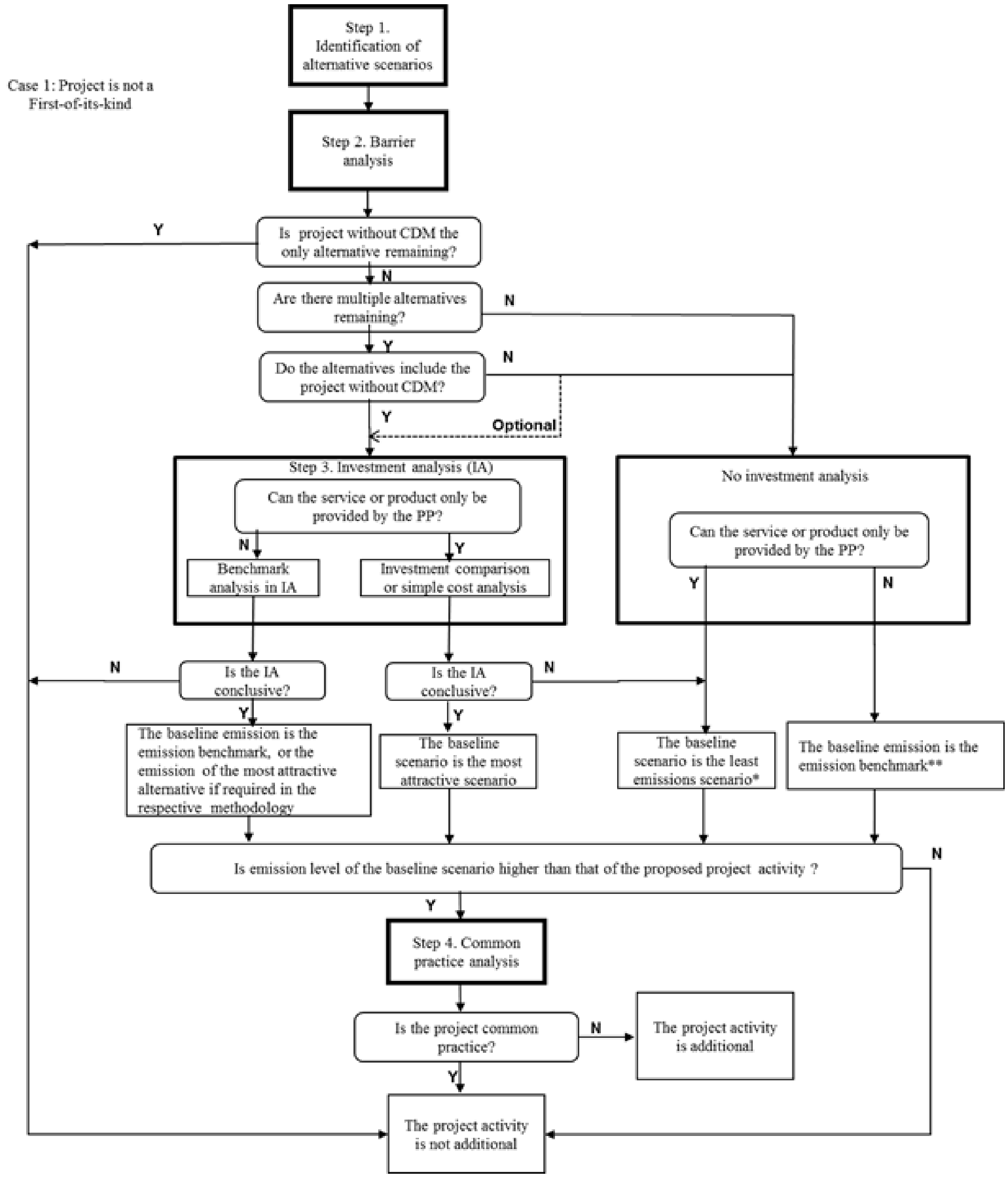

Figure 3.1 Flowchart of the baseline and additionality assessment under CDM

Source: CDM combined tool to identify the baseline scenario and demonstrate additionality.
Note: resolution is as published.

The baselining and additionality tool requires five steps[34]:

- **First-of-its-kind assessment**
  - If listed in the "Methodological tool: Additionality of first-of-its-kind project activities" then the tool shall be applied.
  - Otherwise, the proponent must propose a basis to identify whether the project is first-of-its-kind.
- **Identification of alternative scenarios to produce the same output**. The scenarios should be consistent with applicable mandatory laws and regulations unless it is possible

[34] Note that in the standalone additionality tool the order of the barrier analysis and investment analysis is reversed.

to demonstrate that those laws or regulations are not generally enforced. If no other scenario is consistent with legal obligations then the project is not additional:
  - The project activity undertaken but not registered under the CDM;
  - The output will be provided by one or more third parties;
  - Where applicable, continuation of the current situation with no expense or investment;
  - Where applicable, continuation of the current situation with some incurred expense or investment;
  - Other plausible alternative scenarios;
  - Where applicable, the same activity occurring later and outside the CDM.
- **Barrier analysis** (identifying barriers that would prevent the implementation of any alternative scenarios not including CDM registration). The baseline shall be based on either one of the alternative scenarios that is not subject to a barrier, or on an appropriate emissions benchmark[35].
- **Investment analysis** (where applicable). If the barrier analysis does not show a barrier preventing the implementation of the proposed activity without CDM, the proponent must assess whether the project activity is likely to be financially attractive without CDM funding.
- **Common practice analysis.** Even if a project faces a barrier or passes the investment analysis, it may still be identified as non-additional if the activity is considered to be common practice.

In general, baseline emissions are to be assessed on a per project basis following the rules in the relevant methodology and/or baselining tools, but there are a number of activities for which standardised baselines are available[36], primarily baseline values for grid electricity intensities. We are not aware of any available baseline applicable to carbon removal activities.

For CCS projects, assessment of additionality and the baseline is to be done using the appropriate CDM tools, we are not aware of any CCS-specific rules.

Projects in the AFOLU sector are subject to particular baselining challenges, which can include identifying baseline rates of carbon removals. For example, the methodology for afforestation and reforestation (excluding wetlands) requires baseline net GHG removals due to sinks to be calculated as

$$\Delta C_{BSL,t} = \Delta C_{TREE\_BSL,t} + \Delta C_{SHRUB\_BSL,t} + \Delta C_{DEADWOOD\_BSL,t} + \Delta C_{LITTER\_BSL,t}$$

where BSL stands for baseline, and each term must be calculated using the tool for 'Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities'.

While the CDM is a key example of the implementation of active additionality assessment, and has been emulated by several certification schemes for reductions/removals in the voluntary market, the CDM framework for additionality assessment is not without its critics – both those who consider it burdensome and those who are concerned it may not be adequately robust. A 2010 study for DG Clima by the Öko-Institut[37] concluded that many projects certified under the CDM may not have been truly additional. For example, the report argued that for largescale renewable energy projects such as wind power, an investment analysis may not adequately capture the underlying reasons for going ahead with a project, arguing that there may be other strategic reasons that projects in non-market regulatory environments are greenlit, and that therefore it may not be correct to conclude from an

[35] Strictly speaking the emissions benchmark is identified as an alternative scenario in which a party other than the project proponent produces the relevant output.

[36] https://cdm.unfccc.int/methodologies/standard_base/2015/sb4.html

[37] https://climate.ec.europa.eu/system/files/2017-04/clean_dev_mechanism_en.pdf

investment analysis that CDM funding has caused a project to proceed. The analysis also noted challenges of information asymmetry in assessing the financial performance of a project, as validators will not have access to the same full set of data that project developers do.

3.1.3 Long-term storage and liability

For CCS projects, the aim should be permanent storage. The document FCCC/KP/CMP/2011/10/Add.2[38] sets out requirements for selection and pre-injection characterisation of geological storage sites. In the event that a verification report identifies a net reversal due to 'seepage' (leakage) then CER credits corresponding to the amount of the net reversal should be cancelled from the accounts of the project participants. In the event that the net reversal exceeds the number of CERs available in those accounts, the project participants are to be asked to transfer a corresponding number of CERs or of other Kyoto credits (AAUs, RMUs or ERUs, cf. https://unfccc.int/process/the-kyoto-protocol/mechanisms/emissions-trading) to a cancellation registry. In the event that project participants fail to make such cancellations, the liability to compensate the net reversal is transferred to either the host country or to the Annex I country or countries that holds the relevant CERs in its national registry. It is our understanding that this requirement for compensation continues to apply through the monitoring period that follows the end of the last crediting period. Project participants are expected to clearly state the allocation of liabilities during each of the operational phase, closure phase and post-closure phase in the project design document.

A proposed CCS methodology for the CDM from 2006[39] suggested a requirement that, "At the end of the last crediting period, physical emissions due to future CO_2 escapes in the long term, e.g., over 1,000 years will be predicted using the best available knowledge and data at that time and they will be included in the project emissions."

There are also requirements for financial provision to be made in agreement with the host country to cover the cost of ongoing monitoring and with the obligations arising in the event of CO_2 leakage.

For forestry projects, the requirements around non-permanence of removal credits are noteworthy: only temporary credits are issued, which must be replaced by their expiry date by the party who retired them. Two types of expiring certified emissions reductions (CERs) are issued. Temporary CERs (tCERs) are issued based on standing carbon stock in forest stands, and expire at the end of the Kyoto commitment period following the period in which they are issued. Long-term CERs are issued based on net change in carbon stock between two verification dates, and expire only at the end of the crediting period for the project for which they are issued. Any party buying tCERs or lCERs to use as emissions offsets is liable to replace them after their point of expiration (either with new, still-valid tCERs/lCERs or with other types of credit). These credits may also be cancelled in the event that a reduction in carbon stocks in the relevant land areas is identified prior to the normal expiry of the credits.

3.1.4 Sustainability

CDM project developers are able to showcase the sustainable development benefits of their project activities through the sustainable development (SD) tool[40], which contains a short survey on the project's co-benefits, and enable the generation of an automatic sustainable

[38] https://unfccc.int/resource/docs/2011/cmp7/eng/10a02.pdf

[39] https://cdm.unfccc.int/UserManagement/FileStorage/TM0K2CMFAOQZKAGAQJ6RXSSF602Y24

[40] https://www4.unfccc.int/sites/sdcmicrosite/Documents/SDToolFlyer.pdf

development co-benefits report that is then published on the UNFCCC's website for public access.

The rules for CCS state that, “Geological storage sites shall only be used to store carbon dioxide as project activities under the clean development mechanism (CDM) if, under the proposed conditions of use, … no significant environmental or health risks exist.” For forestry projects, it is required to submit a documentation of environmental and socio-economic impact analysis. If significant impacts are detected, impact assessment required (hydrology, soils, risk of fires, pests and diseases, local communities, indigenous people, land tenure, local employment) is mandatory.

3.1.5 MRV

The Kyoto Protocol requires a rigorous MRV system to ensure transparency and precise quantification of GHG reductions and removals declared by projects.

For the monitoring of CDM activities, applicants must submit their monitoring plan where it should be detailed how each data used for estimating anthropogenic removals by sinks of GHG occurring within the project boundary during the crediting period, and for determining the baseline will be collected and archived. Applicants shall also share information on the quality assurance and control procedures that will be put in place for the monitoring process, and all the steps involved in the periodic calculation of the enhancements of anthropogenic removals by sinks by the proposed project, and for leakage effects, if any. Table 3.1 summarises these requirements.

Table 3.1 Summary of monitoring plan preparation requirements

Monitoring Plan Requirements	Instructions for Project Participants
Management of the monitoring plan	List the operational and management structure to be put in place to implement the monitoring plan.
Data provisions	Explain the arrangements that are in place for your project that will ensure that all data monitored and required for verification and issuance is kept and archived electronically for 2 years after the end of the crediting period or the last issuance of CERs, whichever occurs later.
Definition of responsibilities for the data	Include a definition of responsibilities and institutional arrangements for data collection and archiving.
QA/QC procedures	Explain QA/QC procedures planned for the data, or why such procedures are not necessary.
Uncertainty levels, methods, and the associated accuracy level	State the uncertainty levels, methods, and associated accuracy level of measuring instruments to be used for various parameters and variables.
Specifications of the calibration frequency for the measuring equipment	Where there are no specifications either in the selected methodology or from the Board, project participants must ensure the equipment is calibrated in accordance with the local and/or national standards or as per the manufacturer’s specifications. If local/national standards or the manufacturer’s specifications are not available, international standards may be used.

Source: ADB, 2016. Available in https://adb.org/sites/default/files/institutional-document/185390/mrv-manual-cdm-projects.pdf

The proponent is responsible for monitoring actual emissions according to approved methodology outlined in their project documentation and monitoring plan, for managing changes in the implementation in relation to the original project and for producing the monitoring report for a later verification by a designated operating entity (DOE). The DOE will then verify that emission reductions/removals that took place reflect what the proponent accounted for in their original plan, and if legit, they can then approve the issuance of the corresponding CERs/RMUs.

FCCC/KP/CMP/2011/10/Add.2 specifies monitoring rules specific to CCS projects. Monitoring must continue at least 20 years after the end of the last crediting period or the issuance of CERs has ceased. Where seepage of CO_2 is identified after the end of the last crediting period for the project, this must be quantified and reported in monitoring reports.

3.1.6 "The Article 6.4 mechanism"

Article 6.4 of the Paris Agreement establishes a mechanism to allow "a company in one country can reduce emissions in that country and have those reductions credited so that it can sell them to another company in another country"[41]. Decision 3/CMA.3[42] of the Conference of the Parties calls for the review of CDM baseline and monitoring methodologies and related tools with a view to applying them, (revised as appropriate) to the certification of emission reductions under the Article 6.4 mechanism, and also for the review of baseline and monitoring methodologies used by other market based mechanisms. The potential role of removals under the Article 6.4 mechanism has been clarified by a draft recommendation[43] published on 16 October 2023.

This recommendation defines carbon removals as "the outcomes of processes to remove [greenhouse gases] [carbon dioxide] from the atmosphere through anthropogenic activities and durably store [or destroy] them". The draft recommendation includes the following requirements for removals certified under Article 6.4:

- **Regarding quantification and monitoring:**
    - Removals shall be monitored using appropriate quantification and estimation tools, which may include field measurement, measurement through instrumentation, remote sensing and/or modelling.
    - Data and default values shall be used in a way that is robust, statistically representative and conservative.
    - Uncertainty should be assessed, and where uncertainty exceeds set thresholds, calculated values should be adjusted in a conservative manner.
    - Applicants for certification will require the submission of monitoring plans at the registration or renewal of a project.
- **Additionality and baselining**
    - "Removals to be credited shall be those in excess of the baseline while deducting any activity and leakage emissions" – the draft recommendation does not further define the baseline.
    - An associated information note[44] states that, "The removals achieved by an activity must be additional to the removals that would occur in the baseline",

[41] https://unfccc.int/process-and-meetings/the-paris-agreement/article-64-mechanism

[42] https://unfccc.int/sites/default/files/resource/cma2021_10a01E.pdf

[43] https://unfccc.int/sites/default/files/resource/a64-sb008-aa-a15.pdf

[44] https://unfccc.int/sites/default/files/resource/a64-sb005-aa-a09.pdf

and identifies four types of additionality assessment – financial additionality tests, regulatory additionality test, common practice tests and performance-based additionality tests. The information note suggests that a project should have to pass the additionality tests that "are most relevant to its design".

- **Long term storage and liability:**
  - Monitoring shall be continued following the closure of the final crediting period in a way that is commensurate with identified reversal risk, and may be required to continue until reversal risk is deemed negligible.
  - Provision may be made for responsibility for reversals to be transferred from a project operator to the host country.
- **Sustainability**
  - Projects should assess environmental and social impacts, including by application of the Article 6.4 mechanism sustainable development tool[45] and by imposition of appropriate best practice requirements by the Supervisory Body.

3.2 ISO 14064-2

ISO 14064-2[46] (henceforth 'the ISO') specifies principles and requirements and provides guidance at the project level for quantification, monitoring and reporting of activities intended to cause GHG emission reductions or removal enhancements. We have considered the second edition of ISO 14064-2, dated April 2019. It is part of a series of GHG-related ISO standards along with ISO 14064-1, a standard for organisation level reporting of GHG emissions and removals, and ISO 14064-3, a standard for verification and validation of GHG statements. The ISO does not specify requirements for verification/validation bodies or verifiers/validators in providing assurance against GHG statements or claims by GHG projects. Such requirements may be specified by the authority of the applicable GHG programme or can be found in ISO 14064-3.

The ISO does not prescribe specific criteria and procedures instead it provides general requirements for GHG projects. It is intended that ISO 14064-2 should be used in combination with requirements from specific GHG programmes.

3.2.1 Quantification

The ISO does not provide specific methodologies for the quantification of carbon removals. Instead, it provides an overarching approach for any GHG reduction or removal projects to quantify such reduction in a consistent and robust manner.

As in the CDM, to be compliant with the ISO 14064-2, emission reductions/removals shall be calculated as the difference between the calculated emissions under the project and an emissions baseline. The baseline must be accurate and conservative, in order to provide assurance that emissions are credible and not over-estimated.

The project proponent must establish a monitoring plan and must decide whether each individual relevant emission should be assessed using direct measurement approaches of an alternative approach (e.g. calculation or modelling approaches). In setting the appropriate basis for monitoring of emissions and activity data, project proponents are asked to have regard to any available good practice guidance (and document their use of such guidance),

[45] https://unfccc.int/sites/default/files/resource/a64-sb008-aa-a10.pdf

[46] https://www.iso.org/standard/66454.html

and to consider the principle of relevance; i.e. the cost incurred in monitoring an individual data point should be proportionate to its relevance to accurately assessing GHG emissions. Where the cost of accurate monitoring of a given data point is excessive, the proponent should have regard to the principle of conservativeness when adopting estimation techniques; i.e. the use of estimation approaches should not be allowed to inflate the calculated GHG emissions reduction/removal for the project. Where using standard data (e.g. emissions factors)

The ISO does not set requirements for the project boundary as such, instead requiring project proponents to identify all 'sources, sinks and reservoirs' (SSRs) that are 'relevant' to the project. The ISO includes a detailed decision tree to help project proponents determine which SSRs should be considered relevant. Relevant SSRs include those controlled by the project proponent or related to the project by flows of energy or materials. Some potentially relevant SSRs may nevertheless be unaffected by the project, and therefore may be excluded from monitoring requirements.

Once SSRs have been mapped, the methodologies and parameters needed for estimating emissions from each SSRs shall be identified and the corresponding data collected. ISO requires collection data at the planning stage for quantifying the GHG baseline data, and the collection of data post-implementation of the project for quantifying the project emissions.

The ISO notes that data quality can be improved by performing uncertainty assessment for the data collected. An uncertainty assessment is performed during the planning phase. It may be quantitative or qualitative, but it will generally not involve a statistically rigorous uncertainty analysis – for example, the uncertainty in monitored parameters could be characterised as high, medium or low. A more detailed uncertainty analysis may be appropriate during the implementation phase once project data starts to become available. The ISO anticipates that individual GHG programmes will decide and stipulate whether an uncertainty analysis is required for implemented projects.

3.2.2 Indirect emissions and leakage

The ISO calls for the project proponent to also be accountable for indirect emissions, giving as an example the risk of a rebound effect from an energy efficiency project (where, by reducing energy demand, a project could reduce energy prices and thereby induce additional energy consumption outside the project).

3.2.3 Additionality and baselining

The ISO anticipates that detailed additionality requirements will be set by specific GHG programmes, and therefore such requirements are not included in the ISO itself. It is stated that, "the GHG project should result in emission reductions or removal enhancements in addition to what would have happened in the absence of the project" but does not include requirements for any additionality test itself.

The baseline scenario is defined as the hypothetical reference case that best represents the conditions most likely to occur in the absence of a proposed GHG project. The ISO echoes the CDM by calling for proponents to identify all potential baseline scenarios during the project planning stage, and asking that the selected baseline should be conservative and should be "plausible over a range of assumptions for the duration of the baseline scenario application". Baselines may be constructed based on consideration of historical conditions, market conditions and/or best available technology considerations.

Methodologies to estimate the GHG baseline are generally developed by the project proponent or standardised (i.e. developed by the project proponent or programme authority for specific project types).

3.2.4 Long-term storage and liability

The ISO applies both to GHG reduction and removals projects, and therefore it does not set a single standard for permanence. It requires that the project proponent should assess the risk of a reversal of a GHG emission reduction or removal enhancement but does not make any prescription about how risks of non-permanence should be addressed. The ISO also makes no prescription about liabilities in the case of reversals.

3.2.5 Sustainability

The ISO sets no sustainability requirements in itself, but notes that, "The project proponent may have to complete an environmental and social impact assessment, demonstrate a contribution to sustainable development, and plan the project to be consistent with national environment and development priorities and strategies."

3.2.6 MRV

The ISO requires project proponents to develop detailed monitoring plans as part of project planning. This must include documentation of "procedures for measuring or otherwise obtaining, recording, compiling and analysing data and information important for quantifying and reporting GHG emissions and/or removals relevant for the project and baseline scenario (i.e. GHG information system)." The ISO does not set requirements for either verification or validation, as it anticipates that such requirements will be set by GHG programmes. However, it does require that if the project proponent requests verification and/or validation of the GHG project, this should conform to the principles and requirements of ISO 14064-3.

3.3 Puro.earth

The Puro standard applies exclusively to carbon removals, and it is described as the first carbon removal standard for engineered carbon removal methods in the voluntary carbon market. Here we have reviewed version 3.0 of the Puro Standard General Rules[47]. The Puro standard consists of methodologies for carbon removal through products or processes that remove carbon from the atmosphere, and the Puro states that the methodologies are aligned to the IPCC definition of carbon removals[48]. The removal methodologies considered for this paper under the Puro standard are:

- biochar (2022 edition, v2);
- carbonated materials (2022 edition);
- geologically stored carbon (2021 edition);
- enhanced rock weathering (2022 edition); and,
- woody biomass burial (2022 edition; since updated and renamed in the 2023 edition to 'terrestrial storage of biomass') .

The Puro standard credits only net removals, and credits are always issued ex-post after the removal has been produced. Puro.earth's carbon credit is called 'CO_2 Removal Certificates' (CORCs). Where CO_2 is to be stored, only CO_2 from biogenic origin or from direct capture is eligible. Puro has an external Advisory Board that oversees the methodologies, which specify boundaries, carbon accounting formulas, environmental safeguards, and the required documentation. The CORCs are issued in the Puro Registry where the full lifecycle is tracked from issuance to retirement, ensuring the avoidance of double counting. Puro is part owned

[47] We note that the Puro standard has since been updated to version 3.1 https://connect.puro.earth/puro.earth.rules

[48] Anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.

by the Nasdaq stock exchange, and the Nasdaq publishes price indices on CORC transactions. The CORC Carbon Removal Price Index family consists of a composite index that tracks the price of all CORC transactions as well as separate indices for biochar and bio-based construction materials.

3.3.1 Quantification

The quantification requirements for each type of project are set in the project-specific methodologies, and are quite distinct between methodologies.

The biochar methodology defines the delivered removals as the amount of CO_2 stored minus the sum of: emissions from biomass production and supply; emissions from conversion of biomass to biochar; and emissions associated with use of the biochar. The amount of CO_2 stored in biochar is defined based on the expected carbon content after 100 years (see Section 3.3.4 on long-term storage and liability).

The emissions associated with biomass production are to be assessed on a lifecycle basis, including accounting for “all activities involved in the biomass cultivation and harvesting process”, for “emissions arising from transport of the biomass from the harvest site to the biochar production site“ and for any ‘direct’ land use changes. This framing echoes the RED II and requires that the LCA shall follow the general LCA principles defined in ISO 14040/44, but the standard is not otherwise prescriptive about the details of the lifecycle assessment framework to be used (e.g. it does not prescribe a source of lifecycle inventory data). For the biochar production step, the standard requires assessment of both operational emissions and of emissions associated with capital equipment (e.g. pyrolysis reactor). In the case that co-products are produced along with the biochar (e.g. pyrolysis oil) then an emissions allocation may be required between outputs. The standard takes a similar approach to the RED by requiring an energy-based allocation of emissions between the biochar and any ‘high value’ co-products, while requiring that no emissions are allocated to ‘unimportant’ co-products (analogous to the RED treatment of wastes and residues).

Under the carbonated material production methodology, the delivered removals are defined as the amount of CO_2 stored minus the sum of: emissions from production of the carbonated materials; and of the amount of CO_2 that would be stored under baseline conditions. The amount of carbon stored must be calculated by multiplying the amount of carbonated material produced by a coefficient for carbon stored per tonne of product. This coefficient should be calculated based on “laboratory measurements or other scientifically sound methods” approved by a qualified auditor. Production emissions must be assessed using a LCA approach, and in the case of co-products an allocation of emissions should be made using a methodology consistent with ISO 14040/44. Baseline rates of carbon storage should be assessed in the case that the baseline involves the use of naturally reactive materials susceptible to spontaneous mineral carbonation. The baseline storage term should include expected carbon storage over 50 years of use of the baseline material. The production emissions include production and supply of consumed/used materials, sourcing of CO_2, production of the building material but excludes the distribution of the building material, the use phase and the EoL of the building material (as these are presumed to be comparable between the project and baseline, and to be attributable to the building rather than to the associated carbon removal activity).

Under the geologically stored carbon methodology, the delivered removals are to be calculated as the quantity of CO_2 captured minus the sum of: CO_2 emissions from the project; and CO_2 losses during transport and storage. In the case of DAC, the project operator must demonstrate that the CO_2 is of atmospheric origin, while in the case of biogenic CO_2 the operator must use carbon isotope testing to demonstrate the biogenic origin of the CO_2.

Project emissions are defined as the sum of Scope 1 and Scope 2[49] emissions from capture, transport and storage of the CO_2, plus emissions associated with production of consumed chemicals and materials, and construction emissions from purpose-built equipment. In the case of enhanced oil recovery the current requirement is that "the quantity of the oil extracted from the same reservoir is deducted (in $kgCO_2e$) from the quantity of CO_2 injected (in $kgCO_2$)", which would make it very difficult to register significant net carbon benefits. We understand that this methodology is going to be revised to exclude EOR entirely.

For enhanced rock weathering (through the application of pulverised rock to soil), removals must be simulated prior to project implementation, and evidence must be provided of the composition of the weathering material and of the local soil conditions. The proponent must perform in-field measurements on at least an annual basis to validate the simulated rate of carbon removal. Project emissions must be calculated with a lifecycle assessment quantifying GHG emissions associated with the project (following LCA guidelines in ISO 14040/44). Processes within the system boundary include: rock mining; material processing; transportation; application; in-situ weathering, including direct land use changes; and, potential for reversals in environment (including in the case of movement of material in the environment, such as if washed into rivers).

The methodology for woody biomass burial requires delivered removals to be calculated as the amount of CO_2 stored, minus the sum of: emissions from the biomass supply chain and the establishment, operation and decommissioning of the production facility; leakage emissions due to changes in carbon stocks outside the project's geographical boundaries; end of life emissions from decommissioning and the liability period (to be including only in the 'last years' of operations). The amount of carbon assumed to be stored is calculated using a '100-year stability factor' (see section on long-term storage below). The methodology allows the carbon content of wood to be treated as 50% in the absence of laboratory data. Supply chain and operational emissions shall be calculated using lifecycle assessment, including emissions for capital equipment. The woody biomass burial methodology is considered to be in a pilot phase, which will remain open until only 1st December 2023.

3.3.2 Indirect emissions and leakage

Indirect emissions, characterised as 'leakage' emissions in the general rules and defined as increases in fossil fuel emissions outside the project activity boundary, are to be assessed, quantified and deducted from the carbon removals where required by the individual methodologies.

The enhanced weathering methodology includes a requirement to consider leakage, "if the weathering material (whether a primary product or a burden-free co-product) was already used to deliver another product or service, and thereby possibly entail the extraction of additional primary material, if demand persists. In that case, the LCA shall include primary material extraction." The geologically stored carbon methodology requires that the GHG emissions associated with energy use for CCS should be counted towards project emissions but excludes "renewable energy leakage" from the calculation, stating that the "CO_2 Removal Supplier is not responsible for the availability of renewable electricity in the local market."

While the general rules identify leakage with additional fossil fuel emissions, the woody biomass burial methodology uses a slightly broader definition of leakage emissions: "A decrease in carbon dioxide sequestration or increase in emissions outside the boundaries of the project [Production Facility], resulting from project implementation. Leakage may be caused by the shifting activities or by market effects whereby emissions are generated, or

[49] The geologically stored carbon methodology uses the scope language of the GHG Protocol rather than the language of lifecycle assessment, but the meaning is comparable.

carbon sinks are decreased by shifts in supply of and demand for the products and services affected by the project." It calls for an assessment of potential leakage which should consider potential alternative uses of the biomass and of the land where the biomass is produced, and alternative use of the disposal site. The updated 2023 methodology for Terrestrial Storage of Biomass builds on these requirements with detailed requirements for economic leakage prevention in biomass sourcing. In contrast, the biochar methodology does not currently identify any leakage emissions to be considered (e.g. direct land use change is to be assessed, but there is no consideration of indirect land use changes).

3.3.3 Additionality and baselining

The Puro standard requires that the "CO_2 Removal Supplier shall be able to demonstrate additionality, meaning that the project must convincingly demonstrate that the CO_2 removals are a result of carbon finance." The standard therefore requires a financial analysis, as well as a regulatory surplus test. The financial test is only briefly described, "To demonstrate additionality, [the] CO_2 removal supplier must provide full project financials and counterfactual analysis based on Baselines that shall be project-specific, conservative and periodically updated." Even with substantial non-carbon finance support, projects can be additional if investment is required, risk is present, and/or human capital must be developed.

Suppliers must also show that the project is not required by existing laws, regulations, or other binding obligations. Some of the Puro methodologies also reference the 'Microsoft criteria for high quality carbon removal'[50], which also include a requirement for a commons practice test which is not (to the best of our understanding) required for the Puro standard.

For most of the Puro methodologies considered, the default baseline is implicitly set as 'no action', i.e. zero emissions, however the methodology for carbonated construction materials actively includes a baseline term in the equation for delivered removals that reflects natural rates of mineral carbonation, while the enhanced rock weathering methodology requires consideration of soil related GHG emissions in a non-application baseline.

3.3.4 Long-term storage and liability

Long-term storage is defined as a minimum of 100 years. Puro characterises the lifetime of carbon storage for the allowed approaches as follows:

- Biochar, 100+ years;
- Geologically removed carbon (geological storage), 1000+ years;
- Carbonated materials, 1000+ years;
- Enhanced rock weathering, 1000+ years; and,
- Woody biomass burial, 100+ years.

The methodologies generically state that, "GHG emission reductions or removals from the mitigation activity shall be permanent, or if they have a risk of reversal, any reversals shall be fully compensated".

We note that the Puro rules anticipate the creation of an intermediate form of certificate at some future date, with a relaxed requirement on CO_2 removal longevity. These certificates would be for 'delayed' carbon emissions, rather than for carbon removal ("In the future, it might be possible to include a new type of certificate which doesn't comply with the CO_2 Removal longevity requirement of the current CORC. In such case, the process is called delaying of CO_2 emissions rather than removal"). .

[50] https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RWGG6f

For CCS, “stored permanently means that CO_2 or carbon-containing substance is stored in geological storages in deep, confined rock formations from where the CO_2 cannot escape back to the atmosphere”. it is required that storage sites are permitted following relevant local regulation – EPA Class VI in the U.S., CCS Directive in the EU, or ‘similar criteria’ in other locations.

The biochar methodology requires the project proponent to estimate the amount of CO_2 that will be stored in biochar after 100 years, based on a model in an academic paper by Woolf et al. (2021)[51]. This residual carbon storage is the basis for the number of CORCs awarded to the project. The permanence factor is then a function of average local soil temperature and of the ratio of hydrogen to carbon in the biochar. Warmer temperatures and higher hydrogen content lead to more rapid carbon loss. As the current temperature is to be used, and as global heating will typically lead to increases in local average temperatures, there may be a slight tendency for this equation to overestimate the permanence of biochar in soils, although this effect will be modest for average temperature changes of the order of 2°C. In the absence of equivalent analysis for non-soil applications of biochar, the same permanence fractions are to be used in non-soil applications, which is considered a conservative approach. The maximum permissible hydrogen:carbon ratio for biochar under the Puro certification is 0.7. As we understand the methodology, there is no requirement for ongoing measurement to validate the utilised permanence factor. This is justified on the basis that the permanence factor reflects the current scientific understanding, that the risk of other reversals is considered low, and that it is not possible to precisely assess long-term biochar residence through on-field monitoring.

The biomass burial methodology requires the calculation of a 100-year stability factor for buried carbon. The default stability factor for woody biomass is 91.2%, which is based on the IPCC guidelines for assessing carbon loss from solid waste in landfill. Proponents may propose alternative project specific values based on scientific research, or on analysis of data from analysis of material in the ‘Burial Chambers’. In the event that a more favourable stability factor is agreed, it may be possible to claim back-credits from previous reporting periods. The risk of reversals is considered greater for woody biomass burial than for carbon removals approaches where carbon is stored in a less volatile chemical state, and therefore there are additional requirements on these projects. A monitoring plan must be agreed to detect compromised burial chambers. With the appropriate risk mitigation, Puro argues that the risk of major reversals is low. The project operator is liable to ensure that the post-closure plan on the burial site is upheld for at least 100 years to ensure continued carbon storage. The operator must set up a Trust under local law to handle decommissioning and any required land rehabilitation. In the event of unforeseen reversals (in excess of the expected 8.8% decomposition and leakage default value from IPCC) then the Trust will be used to allow the recovery or remediation of the burial chamber.

As regards liability, in case that an annual Output Audit finds that too many CORCs have been issued, certificates may be withdrawn from the CO_2 Removal Supplier’s account. Where these CORCs are no longer in the CO_2 Removal Supplier’s Account, a corresponding amount of other CORCs, which “are of similar financial value to ensure that no unjust enrichment occurs”, may be withdrawn. It was not clear to us what recourse is available in the case that an Output Audit identifies a discrepancy and the supplier has no CORCs in its account. In the case of a methodology such as biochar where (as we understand it) there is no monitoring for later reversals (e.g. due to fire) there is effectively no ongoing liability.

The Puro standard includes a principle of no double counting/double claiming, i.e., that where carbon has been removed to generate a CORC no party should also count the benefit of that carbon removal in a second carbon inventory or in marketing. The standard requires

[51] ‘Greenhouse Gas Inventory Model for Biochar Additions to Soil’ https://pubs.acs.org/doi/10.1021/acs.est.1c02425

contracts or attestations that there may be no double counting by a third party, for example claims may not be made on the carbon removed by both the capture operator and the storage operator, and if carbon removals are used to generate credits they may not also be taken as a credit in company GHG reporting. No marketing claims of carbon neutrality are to be made by the project operator if the CORC has been sold to and cancelled by a third party. Puro[52] is responsible through contractual and other means to ensure that no volume of output is duplicated in the Issuance and that the retirement of CORCs represents the sole ownership of the CO_2 removal attributes. Puro has the right to perform ad-hoc audits concerning retirement and associated claims.

3.3.5 Sustainability

The Puro standard requires that suppliers should comply with local laws and shall be able to demonstrate ‘Environmental and Social Safeguards’ and that the production facilities should do no harm to the surrounding natural environment or to local communities. This may be demonstrated through an Environmental Impact Assessment, and environmental permit, or ‘other documentation’ approved by Puro. The minimum set of environmental impacts to be considered are: human health; biodiversity; flora; fauna; soil; air. The minimum set of social impacts to be considered are: effects on local communities (including free, prior and informed consent); indigenous people; land tenure; local employment; food production; user safety; cultural and religious sites.

Individual methodologies may set additional sustainability requirements. For example, the biochar methodology sets a requirement for forest biomass that sustainability certificates must be presented from a ‘reputable’ sustainable forest certification programme deemed eligible by Puro, and that non-forest waste biomass must be sourced ‘sustainably’, although in the absence of further specification of how ‘sustainably’ should be understood in this requirement it is unclear how impactful these requirements will be.

3.3.6 MRV

Puro states that its MRV processes are aligned to the requirements of the Integrity Council for the Voluntary Carbon Market’s (IC-VCM) Assessment Framework. The requirements for monitoring in the individual methodologies are stated rather briefly. Under the geological storage methodology, where biomass is used as feedstock, the document states that monitoring and verification shall be done according to the process defined by the REDII Directive, and as implemented by National authorities.

A third-party verification by an approved auditor is required, and Puro states that it trains auditors on the application of each methodology, but as we understand the Puro rules there are not detailed specifications provided to auditors in relation to measurement practice, uncertainty assessment and so forth.

3.4 VCS

One of largest standards used to certify carbon offsets in the voluntary markets, the Verified Carbon Standard (VCS) – formerly known as Voluntary Carbon Standard – is administered by Verra and supports projects across a wide range of sectors through the verification of carbon reduction and removals and issuance of verified carbon units (VCUs). The VCS allows projects under 16 sectoral scopes:

[52] The Body responsible for Issuing CORCs, for operating the System and for overseeing the reliability of the System, which is currently Puro.earth Oy.

- Energy (renewable/non-renewable)
- Energy distribution
- Energy demand
- Manufacturing industries
- Chemical industry
- Construction
- Transport
- Mining/Mineral production
- Metal production
- Fugitive emissions – from fuels (solid, oil, and gas)
- Fugitive emissions – from Industrial gases (halocarbons and sulphur hexafluoride)
- Solvents use
- Waste handling and disposal
- Agriculture, forestry and other land use (AFOLU)
- Livestock and manure management
- Carbon capture and storage

Of these, AFOLU, CCS and potentially construction are the most likely to be relevant to carbon removals projects. The VCS has 46 approved project methodologies, and 53 modules to support various aspects of project assessment. These cover calculation of emissions from a range of sources, boundary setting, additionality assessment, even domesticated animal populations assessment for manure management projects. The VCS standard already includes requirements for geological carbon storage[53], and a CCS methodology is in the process of development with the CCS+ Initiative (see Section 3.5).

Shortly before submission of this review, Verra released Version 4.5 of the VCS Standard[54], in which the program states that it has strengthened the standards' integrity by updating environmental and social safeguards, increasing non-permanence risk withholdings that account for future climate change impacts, and added new requirements for extended minimum permanence monitoring (40 years), among other things. These updates are not considered in this review.

3.4.1 Quantification

The VCS programme has its own methodologies to support the quantification of GHG benefits of a project and to generate Verified Carbon Units (VCUs). Such methodologies provide requirements and procedures that project proponents should follow to determine project boundaries and quantify the GHG emission reductions or removals.

At the time this paper has been prepared, the programme included a few methodologies related to removals due to land use or avoided deforestation. In terms of industrial removals, the programme has two methodologies that could be of relevance: CO_2 Utilization in Concrete Production (VM0043, v1.0) and Biochar Utilization in Soil and Non-Soil Applications (VM0044, v1.1). The CCS+ methodology framework, which was under consultation during the development of this review, will become part of the VCS approved methodologies once published. The CCS+ methodology allows applications that are tailored for a diverse set of capture, transport, and storage technologies. The CCS+ approach is reviewed in the following section 3.5 – the remainder of this section discusses the general VCS rules and details of the concrete and biochar methodologies.

Alternatively, projects seeking registration in the VCS programme may submit a methodology idea note to propose a new or revised VCS methodology or may use methodologies from

[53] https://verra.org/wp-content/uploads/2022/12/GCS-Requirements-v4.0-FINAL.pdf

[54] https://verra.org/verra-releases-version-4-5-of-the-vcs-standard/

other approved GHG programmes, including CDM methodologies and Climate Action Reserve (CAR) protocols.

3.4.2 Indirect emissions and leakage

The VCS defines leakage as “net changes of anthropogenic emissions by GHG sources that occur outside the project or program boundary, but are attributable to the project or program”. This definition covers both upstream emissions that are often characterised as ‘direct’ emissions in the language of lifecycle analysis (and which we considered under the heading ‘quantification’) and market mediated emissions that are often characterised as indirect in the language of lifecycle analysis. Any leakage emissions in either sense shall be subtracted from the number of GHG emission reductions and removals eligible to be issued as VCUs. The program requires and ex-ante estimation and ex-post accounting (i.e., at each verification). Under limited circumstances, projects proponents may apply optional default leakage deductions at validation.

For CO_2 Utilization in Concrete Production projects no indirect emissions are identified in the methodology[55].

For Biochar Utilization in Soil and Non-Soil Applications projects, the methodology states that emissions due to activity-shifting leakage or biomass diversion are considered zero, as currently only waste biomass is eligible for biochar production under this methodology. The waste status of the biomass is to be demonstrated by considering disposition of source biomass for the five years previous to project implementation. It must be demonstrated with appropriate records or attested by the relevant manager/landowner/supplier that the biomass was not used in the five years preceding the project start date (noting that ‘new’ sources of biomass are nevertheless eligible, i.e., the statement must cover only that part of the past five years in which a biomass feedstock was being produced). Note that there is no requirement for a robust analysis of potential alternative disposition of new biomass sources. If a biomass source was previously part-utilised, it must be demonstrated that the total supply is adequate to meet both the existing and new demand. Where the source of biomass cannot be identified, it must be shown that there is an excess supply of that type of biomass in the region in general. There is no requirement to consider the potential for changes in carbon stocks in, for example, deadwood due to changes in biomass utilisation.

For AFOLU projects, the programme suggests “leakage management zones” are included as part of project design. Such an approach could help to minimise the displacement of land use activities to areas outside the project area by “*maintaining the production of goods and services, such as agricultural products, within areas under the control of the project proponent or by addressing the socioeconomic factors that drive land use change*”. Categories of leakage emissions are identified in individual methodologies – for example VM0005 “Methodology for Improved Forest Management: Conversion of Low Productive to High-Productive Forest” identifies a risk of market mediated leakage if a project results in a reduction of harvest levels in the project area, and requires credit adjustments for this leakage depending on whether harvesting is likely to be displaced to forests that are more, less or similarly carbon dense.

[55] In this methodology, some off-site emissions such as electricity generation are treated as project emissions rather than as leakage emissions, suggesting that there is some inconsistency in the precise delineation of emissions sources between methodologies. Upstream emissions from fuel production, which are included as leakage emissions in the draft VCS DAC methodology (see below in section on CCS+), appear to be excluded entirely from the CO_2 in concrete methodology.

3.4.3 Additionality and baselining

VCS methodologies set project-type specific additionality requirements, and some also refer to the use of external additionality tools. VCS allows methodologies to use a project method, performance method and/or an activity method to demonstrate additionality.

If using the project method, methodologies must require at least a regulatory surplus test, the identification of some form of barrier, and a common practice analysis (although a common practice may still be additional if it can be demonstrated that it faces barriers not faced by the existing projects).

If using a performance method, methodologies must require a regulatory surplus test and the use of a performance benchmark. This approach is comparable in principle to the additionality approach envisaged in the proposed CRCF regulation, with the performance benchmark playing the role of the standardised baseline.

If using an activity method, methodologies must require a regulatory surplus test, to confirm that the activity is not mandatory in the jurisdiction where it occur, and a 'positive list' based on one or more of:

- An activity penetration test;
- A financial feasibility test;
- A revenue stream assessment (i.e., identifying that there is no major revenue stream other than GHG credits).

For example, the VCS tool for the assessment of additionality in AFOLU projects[56] lays out a CDM-like series of requirements for the proponent to identify alternative land use scenarios, subject to a regulatory surplus test, an investment analysis and (if the investment analysis does not demonstrate additionality) a barrier analysis, and finally a common practice analysis.

In the biochar methodology the activity method is used. It is noted in the methodology that the penetration of biochar application is (at the time of methodology development) uniformly low in all countries (<5% of technical potential) and in particular that total global biochar production is very much less than the maximum technically possible biochar yield from 100% conversion of all woody residues globally. It is therefore concluded that biochar production passes the activity penetration test. We note that it is not obvious to us that this comparison of existing production versus global technical potential represents a useful metric for quantitative assessment (dividing the quantity of any realised activity by the hypothetical global technical potential for that activity is very often liable to deliver a small number, but this may not convincingly prove that that activity can be considered generically additional). However, the broader qualitative conclusion that biochar production and application has a low market penetration compared to its potential is fair. For areas in which the project activity (biochar use) is considered to have been commercially available in the applicable geographic area for less than three years, however, a barrier analysis is also required, using the CDM *Tool for the demonstration and assessment of additionality*. This extra restriction is presumably intended to control against the case that an activity on a positive list would be widely adopted in a given area for market reasons as soon as it became commercially available and on that basis should not be considered additional – however, it seems that an unintended corollary of this approach is that after three years of failing the additionality test on the basis of not facing a barrier, an activity on a positive list would no longer be subject to a barrier test and may then become additional even if it had already become common practice. It is possible that we have overlooked a detail in the rules system intended to prevent this outcome, as it seems *prima facie* to be problematic.

[56] https://verra.org/wp-content/uploads/imported/methodologies/VT0001v3.0.pdf

For the methodologies under consultation, the use of regulatory and financial additionality is foreseen. For further information on the requirements related to baseline and additionality for the CCS+ methodologies please refer to Section 3.5.

3.4.4 Long-term storage and liability

The VCS system covers a wide range of industrial and non-industrial emissions reductions projects, and does not have a single standard for 'permanent' or 'long-term' carbon storage. VCS uses a buffer pool system to ensure that potential reversals can be compensated. AFOLU projects and geological storage projects under VCS are subject to buffer pool requirements (a similar system is in place under ACR, see 3.6 below). As we understand the VCS rules, buffer requirements do not currently apply to biochar utilisation or to CO_2 enhanced concrete projects. For geological carbon storage, the contribution to the buffer pool is assessed based on a Geologic Carbon Storage Non-Permanence Risk Tool[57].

The standard for biochar utilisation considers reversal risk, but concludes that given the required mitigation actions the reversal risk is minimal – although the required mitigation does not consist of active mitigation measures as such, but rather restrictions on the approved applications. These are, in abbreviated form, that:

- Biochar must be utilised within a year of production;
- If applied to land biochar is not used on wetlands;
- If applied to the soil surface biochar must be mixed with another appropriate substrate;
- Biochar meets the *IBI Biochar Testing Guidelines* or *EBC Production Guidelines*,
- Biochar has an H:C ratio of 0.7 or less;
- Biochar used in industrial applications must come from 'high technology' facilities, meaning that: any pyrolytic gases are recovered or flared; at least 70% of the generated heat is used; appropriate pollution controls must be applied; production temperatures are measured and reported;
- Project proponents demonstrate through lab results or relevant literature that the biochar or final products are 'long lived', i.e. that the biochar remains bound for the lifetime of the product and the biochar in the product is not expected to be combusted at end of life, and that the product meets applicable standards (e.g. for concrete).

The creditable removals are adjusted using a 100-year permanence factor for the biochar – i.e., the quantity credited is consistent with expected remnant carbon after 100 years. Like the Puro standard for biochar, the default permanence factors are based in part on Woolf et al. (2021), but are also informed by IPCC defaults. Echoing the treatment by Puro, in the absence of other evidence non-soil applications are subject to the same permanence factors as soil applications, however VCS allows for proponents to bring their own evidence to propose an alternative value.

3.4.5 Sustainability

As part of the project documentation, the proponent shall demonstrate how the project activities (or additional activities if not directly related to the project) contribute to sustainable development, and requires these to be tracked using the indicators defined by the United Nations Sustainable Development Goals (SDGs). VCS requires that projects contribute with at least three SDGs by the end of the first monitoring period, and in each subsequent monitoring period.

Alternatively, projects with significant SDG benefits may wish to complete a separate verification against one of Verra's parallel certifications: the Climate, Community &

[57] https://verra.org/wp-content/uploads/2022/12/GCS-Non-Permanence-Risk-Tool-v4.0-FINAL.pdf

Biodiversity (CCB) Program or the Sustainable Development Verified Impact Standard (SD VISta) Program. Projects certified under such programs must follow wider assessments, with more rigorous requirements than those certified exclusively under VCS, to demonstrate that the expected co-benefits will be implemented, and tracked.

For the biochar utilisation standard, sustainability risk is to be mitigated through the requirement that biomass for biochar production may not be purpose grown. There is a requirement that it should be demonstrated that when using agricultural residues project activities do not lead to declines in soil carbon stocks or losses in productivity, or else that the baseline treatment of residues was burning, or in the absence of data to demonstrate this it must be demonstrated that no more than 50% of total residues are removed. For forest residues it must be shown that the forest is operated to a management plan approved by a relevant state or regional authority, that the forest is certified to a relevant standard, or that the biomass meets the CDM standard for renewable biomass.[58] The jurisdictions' requirements on water quality, and other mineral rights might not be an impeditive to the project.

3.4.6 MRV

Requirements for the monitoring plan do not differ from those of the CDM. Project data are normally evidenced through invoices from suppliers, but could also be taken from equipment monitoring real-time data. For all injected carbon projects, a continuous monitoring, i.e., every 15 minutes, is required.

As with the CDM, in addition to describing the steps for obtaining, recording, compiling, and QA'ing data or information declared for the project, the monitoring plan shall establish roles and responsibilities. Where data is declared to be measured and monitored through equipment, the project proponent shall ensure the equipment is calibrated according to the equipment's specifications and/or relevant national or international standards.

3.5 CCS+

The CCS+ initiative is a multi-stakeholder initiative to develop certification methodologies for both CO_2 emissions reductions and removals via CCS, and for CO_2 capture and utilisation. In the first instance the methodology will be used to award VCUs under the VCS framework, but in the longer-term CCS+ aspires to engage with a variety of standards operators to support standard development. In the discussion below, we focus on the VCS implementation of the CCS+ standard (and statements about details of the CCS+ approach should be understood as statement about the VCS implementation of CCS+). CCS+ lists 41 partners and ten advisory group members, including the ETIP Zero Emissions Platform. Reductions and removals are to be distinguished by a label in the CCS+ registry.

The CCS+ initiative currently has a draft CCS methodology document and three associated modular documents (DAC, transport, and storage in saline aquifers) available on the Verra website[59]. The CCS+ framework is intended to be modular, and a number of additional module documents are identified as still under development, including BECCS. Projects certified under CCS+ must include both an eligible capture activity and an eligible storage activity, and in the case that CO_2 must be transferred between sites an eligible transport activity. The standard will cover removals from both DACCS and BECCS.

[58] Further requirements are listed for other types of biomass, see Table 1 of the biochar utilisation methodology for a full delineation.

[59] https://verra.org/methodologies/methodology-for-carbon-capture-and-storage/

The published CCS methodology is not applicable to CCU or to storage through enhanced weathering, mineralisation, biochar or ocean alkalinity enhancement. It is not clear from the publicly available documentation when methodologies for CCU and for removals other than DACCS/BECCS may be made available for consultation.

3.5.1 Quantification

To support the quantification of removals, the CCS+ initiative is developing a CCS-specific methodology framework, organised in modules for capture, transport and storage of a CCS project that can be combined, depending on the specific design of the project or technologies implemented.

The CCS Methodology Framework intends to standardise the equations and requirements to enable calculation of different CCS projects, including various types of capturing technologies, the transportation of the CO_2 and the CO_2 storage in saline aquifers, depleted oil & gas reservoirs, and geologic mineralisation.

All the major emissions sources for each stage of the process are captured under the methodology, including emissions from fuel combustion or electricity consumption to operate equipment and conditioning processes, fugitive and venting from on-site fuel use. Emissions of CO_2, CH_4 and N_2O are included in the project emissions assessment (subject to materiality) but CH_4 and N_2O emissions are excluded from the calculation of the baseline for conservativeness.

The CCS methodology proposal sets a materiality threshold of 2% of project lifetime emissions/removals, emissions estimated to be below this level may be excluded from the calculation. The methodology also explicitly excludes emissions from: production and transport of capital equipment; R&D activities; staff commuting; direct and indirect land use change associated with project facilities and equipment.

Any physical leakages occurred during capture, transport, or storage shall be quantified and deducted from the total reduction. Quantification procedures for identifying and estimating such emissions are established in separated technology-specific methodologies. Emissions, such as from power generation and upstream fuel or input production emissions, that might be characterised as lifecycle direct emissions in other contexts (e.g. RED II) are characterised as leakage emissions in VCS, and should be included on a LCA basis.

The DAC methodology requires that grid electricity consumed should be assigned an emission factor based on published emission factors from regional compliance market-approved tools, and /or data published by State or National government agencies (project proponents must reference the sources used and provide evidence of the electricity procurement). Renewable energy (i.e. wind, solar, hydro) from a directly connected, off grid captive source is deemed to have no emissions. Rules for accounting for biomass energy are deferred to a forthcoming methodology document on carbon capture from biogenic sources – the draft text is slightly ambiguous but seems to state that zero-accounting for biogenic carbon only applies if the biomass meets conditions for being sustainable and renewable (i.e. biomass energy not meeting the standard would be accounted as if the CO_2 produced were fossil CO_2 – this treatment echoes the REDII).

The CCS+ BECCS methodology was not yet available to review at the time of writing, but a survey respondent reported that this methodology will assume all projects are ‘brownfield’ plants, i.e., the bioenergy facility was operational before the CCS activity was implemented. This would enable omission of due to bioenergy harvesting, transport, and processing from the scope of quantification.

3.5.2 Indirect emissions and leakage

Neither the DAC nor CCS methodologies identify any emissions that are indirect in the sense of the proposed CRCF Regulation (the methodologies discuss ‘leakage emissions’ but these are limited to upstream emissions in the lifecycle of consumed energy/materials). Prior to the publication of a BECCS methodology it is unknown how changes in bioenergy output due to implementation of carbon capture will be handled.

3.5.3 Additionality and baselining

The methodology states that the baseline for point sources is that the CO_2 captured would have been emitted, and that the baseline for DAC is that the CO_2 captured would have remained in the atmosphere. The methodology states that additional detail will be forthcoming in the modules relevant to specific capture scenarios. In the DAC module, it is stated that the project proponent for a DAC project must demonstrate that in the absence of the project activity no CO_2 capture from the atmosphere would occur. In practice this is reduced to demonstrating that the capture facility is either new or expanded, or would have been decommissioned in the absence of the project activity.

Additionality is to be demonstrated by following the VCS guidelines to prove regulatory surplus, by undertaking an investment analysis using the CDM tool for the demonstration and assessment of additionality and CDM tool for investment analysis (with additional constraints specified by the methodology) and by demonstrating that the project is not common practice (i.e. that carbon capture is not in operation at more than 20% of comparable source facilities, excluding source facilities enrolled in GHG crediting programmes). DAC projects are considered to pass the common practice test by default.

The baselining rules in the CCS+ standard are notable because they carefully distinguish between injection of VCS-eligible and non-VCS-eligible CO_2. Non-VCS-eligible CO_2 would include CO_2 captured from facilities with regulated GHG emissions, as if the benefit of CO_2 capture is already counted towards regulatory compliance it should not be double counted to generate credits in the voluntary markets. The baseline emissions for a CCS+ project are then defined as the total quantity of CO_2 injected at a site, minus the non-VCS-eligible CO_2 that is injected – i.e. the baseline is set as the quantity of non-VCS-eligible CO_2 that would be emitted without capture in the absence of the project.

3.5.4 Long-term storage and liability

At present, the only CCS+ storage methodology relates to underground storage of CO_2, and this storage is intended to be permanent (characterised as successful carbon storage on a timescale of thousands of years) in saline aquifers. This module requires a monitoring programme that “must support the permanent storage of CO_2 injected by ensuring the containment of the plume over time”. The risk of non-permanence of storage must be assessed using the VCS Geological Carbon Storage (GCS) Non-Permanence Risk Tool[60], and credits must be contributed to the GCS buffer account as a form of insurance against reversals. In the event of reversals, credits will be cancelled from the GCS buffer account.[61] If there are not enough credits in the project buffer account to compensate for the reversal, additional credits shall be cancelled from the pooled buffer account to maintain the integrity of the system, and the project shall be expected to ‘repay’ these buffer credits later.

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[60] https://verra.org/wp-content/uploads/2022/12/GCS-Non-Permanence-Risk-Tool-v4.0-FINAL.pdf

[61] The details of this process are set out in the Registration and Issuance Guidance (https://verra.org/wp-content/uploads/2022/12/VCS-Registration-and-Issuance-Process-v4.3-FINAL.pdf), although we note that as of version 4.3 of this document only cancellation from the AFOLU buffer account in explicitly dealt with.

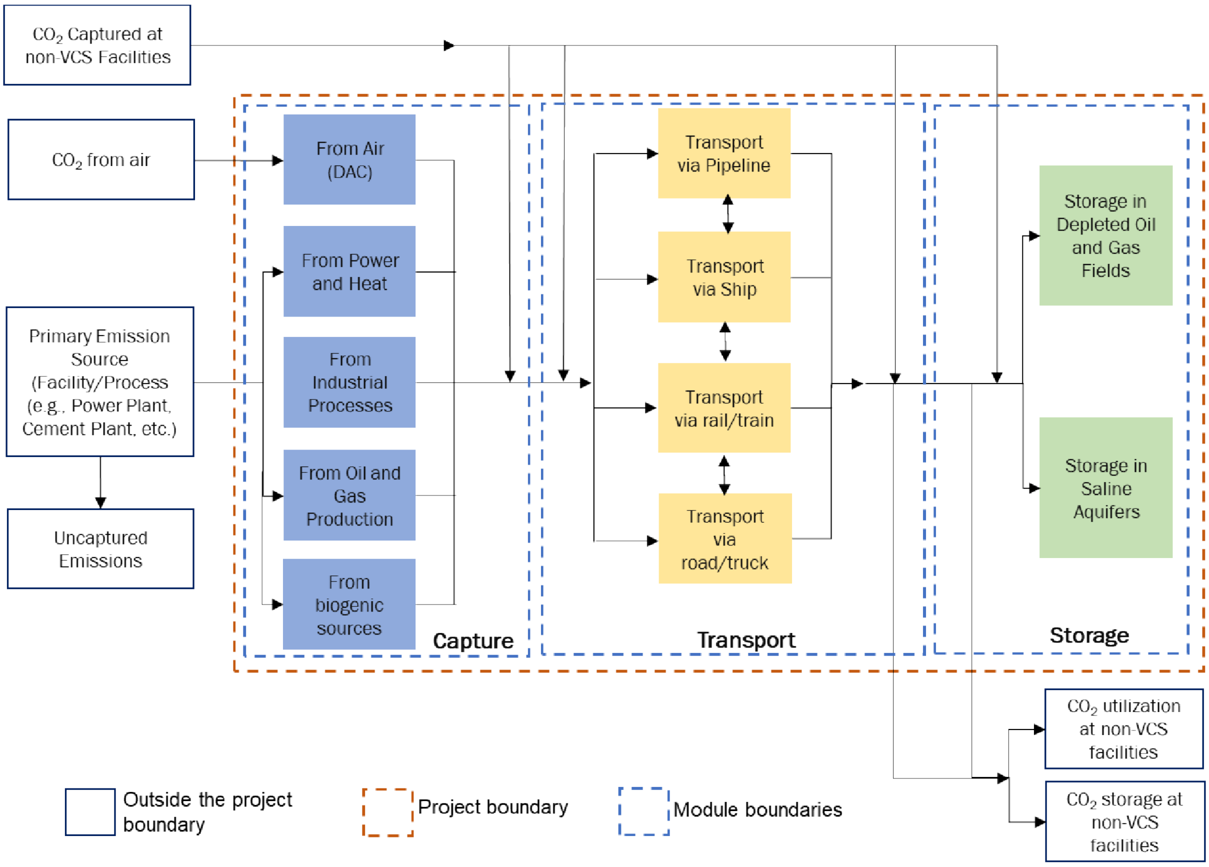
3.5.5 Sustainability

To date, the CCS+ standard does not include specific requirements related to sustainability. Nevertheless, since the initiative intends to have the removals issued under the VCS, it can be assumed that projects adopting this standard will have to comply with similar, if not the same, sustainability requirements, i.e., projects shall demonstrate that contribute with at least three SDGs by the end of the first monitoring period, and in each subsequent monitoring period. A survey respondent indicated that forthcoming methodologies will include rules for identifying biomass sustainability.

3.5.6 Boundaries

The overall project boundary consists of the sum of the activity boundaries as defined under the individual modules. For capture from a source facility, only the elements modified, affected or added to capture CO_2 are considered to be within the project boundary. The CCS+ project boundary is illustrated in Figure 3.2.

Figure 3.2 CCS+ Initiative Project activity boundary illustration



3.5.7 MRV

The draft methodology proposed by the CCS+ initiative, brings a proposal for the MRV section that project developers shall follow when using the methodology to estimate emissions reductions from their projects.

CCS+ MRV approach is consistent with CDM and VCS' approaches, and includes a number of requirements to ensure the traceability of each and every data used in the project design.

In the draft proposal, CCS+ notes that QA/QC procedures must include, but are not limited to:

- Data gathering, input, and handling measures;
- Input data checked for typical errors, including inconsistent physical units, unit conversion errors;
- Typographical errors caused by data transcription from one document to another, and missing data for specific time periods or physical units;
- Input time series data checked for unexpected variations (e.g., orders of magnitude) that could indicate input errors;
- All electronic files to use version control to ensure consistency;
- Physical protection of monitoring equipment;
- Physical protection of records of monitored data (e.g., hard copy and electronic records);
- Input data units checked and documented; and,
- All sources of data, assumptions, and emission factors are documented.

Furthermore, all monitoring provisions related to Geologic Carbon Storage (GCS) as per the latest version of the VCS Program Document VCS Standard and Non-Permanence Risk Tool for Geologic Carbon Storage must comply.

3.6 American Carbon Registry (ACR)

The ACR is a North American programme for crediting GHG reductions and removals administered by the U.S. based non-profit Winrock International. ACR has been approved by the California Air Resources Board for the registration of offset projects under the California Cap and Trade, and by the International Civil Aviation Organisation (ICAO) for the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), as well as for programmes in Washington State and in Colorado. It is the world's oldest privately operated GHG registry. Elements of the ACR standard refer to protocols under the CDM. We have reviewed version 8.0 of the standard, published in July 2023.

ACR credits can be awarded to projects based on either ACR-developed methodologies, approved modifications to ACR-developed methodologies or approved independently-developed methodologies. Potentially relevant approved methodologies include afforestation and reforestation of degraded lands, improved forest management, and carbon capture and storage.

3.6.1 Quantification

The core principles of quantification under the ACR are that all relevant GHG sources, sinks and reservoirs should be identified and considered, and that assessment of GHG reductions should as far as possible be consistent over time, accurate, transparent and conservative. The ACR rules follow ISO 14064-2. ACR requires project proponents to include methods for estimating uncertainty in both the baseline and project scenarios. For sampling-based measures (relevant to AFOLU projects) the ACR sets a maximum permissible sampling error of ±10% - in the case of greater uncertainty, the certifiable emissions are reduced to avoid the risk of over-crediting. Emission factors used in calculations must be of "scientific peer-reviewed" origin and must take account of quantification uncertainty. Project proponents are expected to outline data quality assurance and control measures in the project plans.

The ACR CCS methodology (draft version 2, September 2022) defines delivered reductions as the difference between baseline and project emissions. Project emissions are defined as the sum of emissions from capture and compression, emissions from CO_2 transport and emissions from injection and storage. Emissions to be assessed include emissions from fuel use on-site, emissions associated with generation for consumed energy, and any fugitive/vented emissions of CO_2. The CCS methodology includes a detailed breakdown of emissions sources and sinks across the capture, transport and injection stages. In the case that captured CO_2 is stored through a system of enhanced oil recovery, then the emissions of the produced oil (transportation, refining and end use) are to be considered project emissions. This is a comparable treatment to that in effect under the Innovation Fund, and is a significant revision compared to the current active version of the ACR CCS methodology (v1.1, September 2021) which is only applicable to CCS through EOR, and which we understand does not include any such provision to include emissions associated with the produced oil.

3.6.2 Indirect emissions and leakage

The ACR rules state that, “If an AFOLU project displaces activities, the Project Proponent shall account for the activity shifting (…) Similarly, if an AFOLU project causes market effects leakage, it must be accounted or mitigated.” For example, if an AFOLU project results in a reduced supply of goods then methodologies ‘must provide an approach for addressing this’. ACR defines indirect GHG emissions more generally, but only in order to exclude projects that deliver indirect GHG benefits from being certified. The ACR CCS standard, for example, does not require consideration of any emissions that would be considered indirect in the language of the proposed CRCF Regulation.

3.6.3 Additionality and baselining

In order to be considered additional, the ACR requires either that projects should meet an approved performance standard and pass a regulatory surplus test as defined in the relevant methodology, or that they should meet a standardised ‘three pronged’ additionality test to demonstrate that the project goes beyond legal requirements, goes beyond common practice and overcomes an institutional, financial and/or technical barrier. Some ACR methodologies do not allow a performance standard, for example the methodology for afforestation and reforestation of degraded land requires the three-prong test, which is to be ‘amplified’ by the use of the CDM “Combined tool to identify the baseline scenario and demonstrate additionality in afforestation/reforestation CDM project activities”.

Under the ACR, a performance standard may be:

- **Practice-based**, where if adoption rates of a practice are sufficiently low in the relevant industry/sector and geographical region the practice can be considered uniformly additional in that region;
- **A technology standard**, where if installation of a specified technology is sufficiently uncommon in a geographical region the technology can be considered uniformly additional in that region;
- **An emissions rate or benchmark**, where a GHG performance baseline would be set and any GHG emissions reductions/removals beyond this would be considered uniformly additional.

The performance standard approach might therefore be seen as analogous to the handling of additionality through baseline setting that is suggested in Article 5(2) of the proposed CRCF Regulation.

Under the CCS-specific ACR methodology, it is concluded that CCS projects in the U.S. qualify as additional under a practice-based performance standard provided they are not required by regulation. Regulations that incentivise but do not ‘effectively require’ the adoption of carbon capture (such as the 45Q tax credit in the U.S.[62], or funding from

[62] This is implied in the current v1.1 standard and ACR proposes to make it explicit in the new v2.0 standard.

instruments like the Innovation Fund in the EU) do not prevent a project from passing the regulatory surplus test.

The baseline for CCS projects may be either 'projection-based' or 'standards-based'. The baseline should reflect the emissions required to provide an equivalent function in the absence of the project. The principle of functional equivalence means that the base setting process must consider that the output of a system may be changed by adding a carbon capture unit to it, for example if carbon capture is retrofitted to a power plant it may lead to reduced electricity production.

Under the projection-based baseline approach, the baseline for each year is to be calculated based on the quantity of CO_2 produced in that year by the system to which the carbon capture unit is fitted, adjusted to account for incremental CO_2 associated with running the carbon capture equipment. The ACR guidance anticipates that a projection-based baseline will be used for most carbon capture systems on industrial CO_2 sources, and for all DACCS systems.

Under the standards-based baseline approach, the baseline is to be calculated based on a baseline emissions factor multiplied by the output of the system. A standards-based baseline would only be applied in the case that operation of the system in question would not be permissible without the carbon capture system, for example in the case that a GHG standard applies and would not be met in the absence of the carbon capture equipment. In such a case, the baseline emission factor would reflect minimum permissible performance under this standard.

3.6.4 Long-term storage and liability

The ACR standard notes that, "terrestrial and geologic sequestration projects have the potential for GHG emission reductions and removals to be reversed upon exposure to risk factors, including Unintentional Reversals and Intentional Reversals". Intentional reversals (for example reversals occurring because a project proponent or landowner decides to discontinue an activity) are particularly relevant to AFOLU projects.

For CCS projects, the ACR requires that project proponents should aim for permanent storage, and must demonstrate the presence of a confining layer in the geological storage facility that will prevent atmospheric leakage of CO_2. Leakage must be monitored during and after the duration of the project, and monitoring must continue at least until it can be assured that the CO_2 plume is stable and that there is no leakage of CO_2. The standard includes requirements on assessment of leakage risk and requires operations to confirm to relevant U.S. EPA standards[63]. The project proponent must also file (or cause to be filed by the owner of the storage site) a Risk Mitigation Covenant in relevant property records that prohibits future activities that could cause release of stored carbon, unless any reversal is compensated by replacement of the reversed credits. An annual attestation of compliance must be submitted to ACR and a lien in favour of ACR must be included in the covenant. Responsibility for unintentional leakage ends at the end of the defined post-injection period, but any intentional leakages must be compensated under the terms of the covenant.

For AFOLU projects, a minimum project term of 40 years is required. It is noted that this minimum project term cannot be equated with assurance of permanence, but that 40 years is considered a relevant timeframe from the point of view of the potential achievement of 1.5-degree compatible emissions pathways. AFOLU projects must commit to "maintain, monitor and verify" project activities for at least this 40-year period. AFOLU projects must undertake a Reversal Risk Analysis using an ACR-approved risk assessment tool.

[63] Or equivalent local standards – projects in Canada are expected to meet Canadian requirements.

Projects that are considered to be at risk of reversals (terrestrial and geological storage projects) are required to adopt effective risk mitigation measures to compensate for any loss of sequestered carbon during the project period. Unless a project adopts another acceptable risk mitigation approach, a fraction of the credits generated by the project must be placed into the ‘ACR buffer pool’. In the event of unintentional reversals, credits will be retired from the buffer account of the project proponent. If the amount of the reversal exceeds the number of credits in the account, the project proponent must arrange for the cancellation of ACR credits equivalent to 10% of the excess, and the remainder will be retired by ACR from the general buffer pool. In the case of an intentional reversal, the relevant number of credits must be cancelled from the project proponents’ normal credit account, with the remainder to be cancelled from the buffer pool at the expense of the proponent. When a project ends, ACR cancels the remaining project-related buffer pool credits.

3.6.5 Sustainability

Projects are expected to maintain compliance with all relevant local, national and international laws, regulations, conventions and agreements. ACR also requires project proponents to make environmental and social impact assessments, and to monitor and/or mitigate negative impacts and risks. Project proponents are expected to report on co-benefits of their projects where they constitute positive contributions to any UN Sustainable Development Goals. Monitoring Reports must document any identified negative environmental or social impacts and/or claims of negative environmental or social impacts. In the case that there are environmental or social impacts that cannot be or have not been mitigated ACR reserves the right to refuse to issue credits.

3.6.6 MRV

A monitoring plan shall include all the information for the traceability of the parameters that are used in the calculation, except for the defaults provided by the methodologies. Similar to other initiatives, the ACR sets the minimum necessary information that operators need to provide for initial validation of project plans, as well as for the preparation of GHG statements that will be submitted for verification. The ACR allows for a materiality threshold of ±5% for any discrepancy between the supplier-reported GHG benefits and the GHG benefits calculated by the verifier. In the case of a discrepancy above this threshold credits will not be issued. The project proponent must establish and apply quality control/quality assurance procedures, including activities to minimise uncertainty.

3.7 Climeworks/Carbfix

Climeworks, a company specialising in DAC technology, and Carbfix, a company specialising in carbon mineralisation in carbonate rocks, have collaborated to produce what they describe as “the world's first full-chain methodology dedicated to carbon dioxide removal via direct air capture and underground mineralization storage”[64], and have had the methodology ‘validated’ by the third-party auditor DNV[65]. The system consists of paired methodologies for direct air capture (developed by Climeworks) and for in-situ carbon mineralisation (developed by Carbfix). The DAC standard is informed by ISO 14064-2:2019.

[64] https://climeworks.com/news/methodology-for-permanent-carbon-removal

[65] It is stated that the methodologies were validated against ISO 14064-2 and that DNV validated the methodologies, “by advising on the principles of methodology development and ensuring robustness and accuracy of the approach”.

The Carbfix methodology explicitly excludes forms of geological CO_2 storage other than solubility trapping and in-situ carbon mineralisation and excludes pure-phase injections, such as Enhanced Oil Recovery (EOR) and applications in sedimentary basins.

3.7.1 Quantification

The methodologies relate to the capture and storage phases respectively. A third methodology would need to be utilised to account for emissions from CO_2 transport.

The overall CO_2 removal is to be calculated as the amount of CO_2 injected into an appropriate reservoir minus the sum of: any CO_2 released (e.g. fugitive emissions) downstream of the last injection monitoring point; operational emissions; and embodied emissions from construction and disposal of the project. Embodied emissions are to be assessed on a cradle-to-grave basis. Emissions associated with each part of the system (capture, transport, storage) must be combined to assess net carbon removals, notwithstanding being assessed under different modules. The accounting should include assessment of emissions from construction and disposal of project facilities.

Vented and/or fugitive emissions are to be implicitly accounted by measuring the amount of CO_2 injected at the wellhead of the storage facility i.e., any CO_2 lost during capture and transport will not be measured and will not feature in the net removal accounting.

For the DAC module, emissions from sorbent production and disposal are identified as an important term, and the methodology requires that sorbent consumption should be tracked through the operational phase and that any difference between projected and actual emissions must be reconciled.

3.7.2 Additionality and baselining

Additionality may be demonstrated using the CDM additionality tools, plus a regulatory surplus test. If statutory requirements change during the crediting period of a project resulting the project no longer being additional, this does not affect the current crediting period but prevents the crediting period from being renewed. If emissions reductions are used to contribute to regulatory CO_2 emission requirements (e.g. under the EU ETS) then the project cannot be considered additional and cannot generate certificates. For DAC, baseline emissions are set at zero. The mineralisation standard states that the baseline must be assessed based on the carbon capture activity (it is to be assumed that there would be no mineralisation in the baseline).

3.7.3 Long-term storage and liability

The mineralisation approach aims for permanent CO_2 storage, with the mineralisation process characterised as taking ‘months to years’. The permanence risk for the mineralisation approach is described as ‘negligible’ if sufficient CO_2 reservoir pressure is maintained. The mineralisation standard requires risk analysis and identification of potential leakage pathways from CO_2 degassing. There are detailed requirements on site characterisation before injection begins, and the reservoir must be such that the CO_2 cannot degas (i.e. come out of solution before it has been mineralised) within the reservoir. The reservoir must be monitored, and CO_2 detectors must be placed around the injection site. Following closure, post-closure monitoring must include sampling of monitoring wells and above surface measurements at least every other year. The post-closure period should be at least 10 years, unless 95% CO_2 mineralisation can be demonstrated before that time.

Any CO_2 identified as being accidentally released at the storage site must be subtracted from the amount injected in the calculation of creditable removals for that period. It is our understanding that there is no requirement for cancellation of credits in the event of CO_2 release after closure. They presume liability transfer to the state following the post-closure period.

Where there are multiple Project proponents implementing and operating projects the ownership of climate benefits associated with the geological CO_2 storage shall be clearly defined on a contractual basis, in order to prevent double accounting. Further where there are more than one Project proponent operating the project one shall be assigned overall responsibility of implementation and operation of the project. In order to prevent double counting, the owner of the CO_2 source cannot claim emission mitigations for its own operations due to the operation to the project if climate benefits generated are transferred to a third-party organisation.

3.7.4 Sustainability

There is a requirement for compliance with legal requirements and for no net environmental or social harm, but the standards are not prescriptive about how net harm is to be assessed.

3.7.5 MRV

The objective of the monitoring plan is to quantify GHGs entering or leaving the project boundary (CO_2 capture, CO_2 transport, and CO_2 storage).

The storage methodology includes a detailed listing of relevant parameters to be monitored and a standardised format for characterising those parameters (e.g. fields include data unit, calculation method, monitoring frequency, QA/QC procedures, justification of data source), although not all fields are considered relevant to all quantities, e.g. QA/QC is only specified for measured quantities, not for calculated ones. It provides a detailed specification of monitoring requirements for the storage approach, covering both monitoring for leaks and monitoring to ensure reservoir characteristics are consistent with delivering intended mineralisation and to show that CO_2 concentrations are consistent with ongoing mineralisation. The capture methodology is more generic, essentially repeating the requirement that the wellhead is the key monitoring point for CO_2 volume and that the process emissions should be calculated on a cradle to grave basis.

All measurement devices used must be calibrated according to manufacturer recommendations or industry best practices and allow measurements with uncertainty of 5% or better.

3.8 The GHG Protocol Land Sector and Removals Guidance

Building on the GHG Protocol Corporate Standard and Scope 3 Standard, the GHG Protocol Land Sector and Removals (LSR) Guidance explains how companies may account for and report GHG emissions and removals from land management, land use change, biogenic products, carbon dioxide removal technologies, and related activities in their company GHG inventories.

The Guidance is currently being developed through a global, multi-stakeholder development process which began in 2020. It will build on existing methods and approaches such as IPCC guidelines for national GHG inventories, GHG Protocol Agricultural Guidance and LULUCF Guidance for Project Accounting, ISO 14064-1:2018 etc. The Draft for Pilot Testing and Review is now available[66]. The Guidance is scheduled to be finalised and published in 2024.

[66] https://ghgprotocol.org/sites/default/files/2022-12/Land-Sector-and-Removals-Guidance-Pilot-Testing-and-Review-Draft-Part-1.pdf

It is expected to be used by companies to inform mitigation strategies, understand the GHG emissions/removals, set targets and track performance, report GHG inventories including GHG emissions and carbon removals, and report progress towards GHG mitigation goals. The list of topics to be addressed by the guidance include defining types of removals and storage, accounting methods for removals, quantification methods and data sources, reporting, target setting and tracking changes over time.

The Guidance is intended to be used to compile and report a company's annual GHG inventory. It provides guidance on how GHG removals (which may be certified under one of the certification schemes discussed in this paper) may be identified on a project basis either within the scope of a company's inventory (e.g. assessing GHG removals in the supply chain as a basis to adjust Scope 3 emissions accounting) or outside that scope and reported as a form of offset.

Companies are required to follow the GHG accounting and reporting principles of relevance, completeness, consistency, transparency, accuracy, conservativeness, and permanence when compiling a GHG inventory which includes land sector activities and/or removals. The guidance provides requirements applicable if a company engages in purchases or sales of emission credits or when credits have been generated in the company's value chain.

3.8.1 Quantification

Credited GHG reductions and removals are quantified and reported differently in GHG inventories. These shall be quantified using project or intervention accounting methods, which require comparison of project emissions against a baseline scenario or performance benchmarks that represent the conditions most likely to occur in the absence of the project activity. In contrast, emissions and removals reported in scopes 1, 2 and 3 use an inventory method and are treated as emissions and removals occurring in the company's operations or value chain. The treatment of credited reductions and removals is most relevant to the CRCF.

Companies avoid double-counting between inset credits[67] and the scope 3 inventory by accounting for the impact of activities in the value chain through scope 3 inventory accounting (see Table 3.2). Companies shall deduct emission removals associated with the sale of credits used as offsets from the company's GHG target accounting. This is achieved by calculating separately inventory emissions and removals and those adjusted for sold credits.

[67] The term 'inset credit' is used to refer to activities using the same quantification methods as offset credits but that reduce emissions or increase removals within the reporting company's value chain.

Table 3.2 Accounting for emissions and removals in the GHG inventory vs. accounting for credits[68]

Accounting for:	Description	Accounting method	Quality criteria	Reporting
Emissions and removals in the GHG inventory (scope 1, scope 2, scope 3)	GHG emissions and removals that occur in company operations and value chain	Inventory accounting	• For emissions: n/a • For removals: ongoing storage monitoring, traceability, primary data, uncertainty, reversals accounting (see chapter 6 for more information)	Reported in the scopes (if requirements for reporting removals in chapter 6 are met)
GHG credits (e.g., offsets)	Quantified GHG reduction or removal impacts of projects or interventions, which are credited for GHG claims to be transferred between entities	Project or intervention accounting (relative to counterfactual baseline scenario)	• Additionality • Credible baselines • Monitoring • Permanence • Avoid leakage • Unique issuance and claiming • Independent validation and verification • GHG program governance • No net harm (See section 13.3 for more information)	Reported separately from the scopes

Companies are required to define their organisational boundaries, using equity share, financial control, or operational control, consistently across the GHG inventory, including all accounting categories. Companies are required to separately account for, and report, removals based on sink process (biogenic or technological) and storage pool (land-based storage, product storage or geologic storage).

Reporting removals is optional. Companies may account for and report scope 1 or scope 3 CO_2 removals only if the following requirements are met:

- **Ongoing storage monitoring:** Companies shall account for and report removals only if there is ongoing storage monitoring of the relevant carbon pool(s), as specified through a monitoring plan, to demonstrate that the carbon remains stored or to detect losses of the stored carbon.
- **Traceability:** Companies shall account for and report removals only if the reporting company has traceability throughout the full CO_2 removals pathway, including to the sink (where CO_2 is transferred from the atmosphere to non-atmospheric pools), to the carbon pools where the carbon is stored, and to any intermediate processes if relevant.
- **Primary data:** Companies shall account for and report removals only if the net carbon stock changes are accounted for using empirical data specific to the sinks and pools where carbon is stored in the reporting company's operations or value chain.
- **Uncertainty:** Companies shall account for and report removals only if the removals are statistically significant and companies provide quantitative uncertainty estimates for removals, including 1) the removal value, 2) the uncertainty range for the removal

[68] p. 245 Land-Sector-and-Removals-Guidance-Pilot-Testing-and-Review-Draft-Part-1.pdf (ghgprotocol.org)

estimate based on a specified confidence level, and 3) justification of how the selected value does not overestimate removals.

- **Reversals accounting:** Companies shall account for and report net carbon stock losses of previously reported removals in the year the losses occur, as either: Net CO_2 emissions, if the carbon pools are part of the GHG inventory boundary in the reporting year, or Reversals, if the carbon pools are no longer in the GHG inventory boundary in the reporting year.
- **For geologic storage with enhanced oil and gas recovery**, companies are required to account for all downstream emission associated with extraction, processing, transportation, distribution, storage and use of oil, natural gas or other hydrocarbons produced from the geologic reservoir. In addition, companies shall report on all life cycle emission from cradle to grave including emissions from product life cycle associated with stored CO_2. These emissions are to be reported in the corresponding scope 1, 2 and/or 3.

3.8.2 Additionality and baselining

The additionality criterion for credited GHG removals is that “the project or activity that increases removals relative to the amount of removals that would have occurred without the incentives provided by the credit.” The criterion for baseline setting is that “GHG removals are quantified relative to a realistic, defensible and conservative estimate of GHG removals occurring in the baseline scenario or performance standard. With respect to removals, a credible baseline may be zero if no removals were likely to occur in the absence of the project or activity.”

The detailed implementation of rules for GHG credits, including additionality and baselining rules, is deferred to the GHG programmes under which the credits are generated. To the best of our knowledge the GHG Protocol does not maintain a positive list of eligible GHG crediting programmes.

3.8.3 Long-term storage and liability

The LSR Guidance states that companies shall ensure mechanisms are in place to monitor the continued storage of reported removals, account for reversals, and report emissions from associated carbon pools.

This Guidance uses a storage monitoring framework to implement the permanence principle. Another alternative is a storage discounting framework that uses dynamic carbon accounting methods[69] to account for temporary carbon storage.

Companies must also account for reversals (emissions from the carbon pool that stores carbon associated with removals that were already reported). In cases where companies can no longer monitor carbon stocks associated with reported removals, it shall be assumed that previously reported removals are emitted and reported as reversals.

To report scope 1 net removals with geologic storage when no single entity owns or controls both the sink and the pool of the CO_2 removals, the multiple entities involved in the geologic removal and storage pathway shall develop a contractual agreement which specifies (1) The ownership (rights) of the CO_2 sinks and pools and resulting removals, and the responsibility (obligations) of the GHG sources and resulting emissions (including any reversals) across the entire geologic removal and storage pathway; and (2) Which single entity accounts for the removals as scope 1, and mechanisms to avoid double counting.

[69] Dynamic carbon accounting methods can be used to evaluate the impact on atmospheric radiative forcing of temporarily storing carbon in land-based product or geologic carbon pools.

The permanence criterion for credited GHG removals is to ensure the longevity of the removals for a period of 100 years or other time period which can be defined by the GHG programme.

3.8.4 Sustainability

The draft guidance document supports disclosure under other sustainability reporting regulatory frameworks and initiatives such as ISO 14064, CDP (formerly called carbon disclosure project), CDP Supply chain and Accountability Framework Initiative (Afi), Science Based Targets initiative (SBTi), voluntary carbon market standards and national and regional regulations.

3.8.5 MRV

The GHG Protocol recommends but does not require assurance in line with its assurance guidance; it further recommends but does not require engagement with third party verifiers. As companies are given considerable leeway to decide what level of assurance to apply and what MRV procedures to follow, the GHG Protocol is less relevant in this regard than other more prescriptive standards.

3.9 Global Carbon Council

The Global Carbon Council (GCC) project standard is globally applicable, despite having been developed with a view to supporting project development in the Middle East and North Africa, by the Gulf Organization for Research and Development. It is recognised by ICAO for CORSIA, and builds upon the provisions of ISO 14064-2 and 14064-3. The current version of the project standard at the time of writing was version 3.1. The GCC identifies that a CCS standard is under development but not yet available. The currently available methodologies do not cover projects considered under the proposed CRCF Regulation.

3.9.1 Quantification

Quantification guidelines are set in the project specific methodologies. A methodology for CCS is identified as forthcoming but is not yet available. The other published methodologies are not relevant to carbon removals.

3.9.2 Additionality and baselining

Additionality is to be assessed based on a ‘legal requirement test’[70], plus either the inclusion of the project technology in a positive list of additional technologies (either the CDM global positive list[71] or a GCC-developed regional list included in a relevant methodology) or assessment based on application of the CDM additionality tools.

Baseline scenarios must be determined following the relevant methodology, and must be conservative.

3.9.3 Long-term storage and liability

The standard states that, “Where GHG emission reductions are generated by projects that carry a risk of reversibility, adequate safeguards shall be in place to ensure that the risk of

[70] Equivalent to a regulatory surplus test.

[71] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-32-v4.0.pdf

reversal is minimised and that, should any reversal occur, the equivalent amount of emission reductions shall be replaced or compensated by the Project Owner and/or the GCC verifier."

3.9.4 Sustainability

The GCC rules include the option for projects to voluntarily show that they do not cause any net harm to the environment and society by applying the GCC Environmental and Social Safeguards Standard, and offer two associated certification labels – environmental no-net-harm (E+) and social no-net-harm (S+). They also allow projects to register contributions to the UN sustainable development goals by using the GCC Project Sustainability Standard. The do no harm assessment is based on compliance with applicable laws, and the identification of negative (harmful) and positive (harmless) impacts. The no net harm assessment is somewhat unusual in that it is based on giving each identified impact a score of 1, 0 or -1 and summing these scores. If the summed result is zero or positive, then the project is considered to cause no net harm. Impacts that are positive or that are negative and are adequately mitigated by the project plan are given a score of +1, impacts that are negative and not adequately mitigated are given a score of -1, and impacts that are potentially positive but cannot be monitored are to be given a score of 0. This scoring approach allows an assessment to be made across disparate impacts but includes no scaling and therefore could allow a sever negative impact to be offset by a modest positive one. As mitigated negative impacts are also scored positively, a project with three unmitigated negative impacts and three mitigated negative impacts would be rated as causing no net harm. An approach of this sort is unlikely to be considered satisfactory in the proposed EU certification scheme.

3.9.5 MRV

The GCC Verification Standard provides specific regulations for third-party independent verification of the GHG emission reductions and removals. The standard is linked to ISO 14064-3. Verification of a project activity encompasses among other elements emission reductions, sustainability and environmental and social do-no-harm criteria. A verification takes places prior to project registration and prior to issuance of the certificate. In case of a non-conformity, the verifier raises Corrective Action Requests (CAR) or if information is lacking, a Clarification Request (CR). If issues occur during project implementation that require a review during the first Emission Reduction Verification (checking reported GHG emission reduction against GCC requirements), the verifier can raise a Forward Action Request (FAR). These requests can only be resolved if corrective actions have been taken by the project owner on the raised matters. All CAR, CR and FAR need to be recorded in the project verification report.

3.10 Drax-Stockholm Exergi BECCS methodology discussion draft

This methodology has been developed by two companies, Drax and Stockholm Exergi, both of whom operate existing bioenergy plants and have an interest in adding CCS capacity. The development of the methodology was supported by the consultant EcoEngineers. We have reviewed a draft methodology version numbered V0.9, dated September 2023. The draft methodology applies only to BECCS projects based on capturing CO_2 from thermal combustion of solid biomass, but it is stated that the principles could be adapted for other BECCS approaches (e.g. capture of fermentation CO_2, capture of mixed-CO_2 streams at waste to energy plants). The draft methodology identifies as influences, inter alia, ISO

14064-2 and ISO 27914, the Puro geologically removed carbon methodology and the Gold Standard draft methodology for carbon capture from biomass fermentation.

3.10.1 Quantification

The project boundary is defined on the basis of “processes that are exclusively initiated by the anticipation of CDR credit revenue from the project”. This means that some processes that are required for the operation of the power generation element of a facility are not considered within the scope of the BECCS project. The methodology states biomass cultivation emissions are to be included but that “non-BECCS specific” biomass cultivation and harvesting emissions are excluded from the scope. It is not entirely explicit how “non-BECCS specific” is to be understood. It is our understanding, confirmed by the standard developers, that the intention is that all biomass associated with the fraction of bioenergy production to which CCS is applied would be considered in scope, though with an allocation factor so that only part of the biomass cultivation emissions would be allocated to the CCS project. This allocation factor would also be applied to other emissions (feedstock processing and transportation, ash disposal) that are shared between the energy output and removed carbon (“Operational supply chain emissions can either be fully allocated to carbon removals or be partially allocated against different energy products that may be produced through the bioenergy generation process. The use of the allocation factor is left at the discretion of the project proponent.”).

The allocation factor for supply chain emissions is to be calculated based on the fraction of produced electricity in the total energy output of the plant, multiplied by the fraction of the produced electricity that is consumed in operating the CCS process. The proposed allocation is based on holding the CCS unit ‘accountable’ for the emissions associated with the production of the energy it consumes but does not treat the removed CO_2 as a co-product of the BECCS system to which a larger share of upstream emissions might be allocated, for instance on a value based allocation.

The calculation of emissions associated with the carbon capture unit must include any emissions from additional energy generation, chemical use and chemical production for the carbon capture unit, CO_2 processing and transport, and capital emissions for the CO_2 capture, transport and storage equipment. In the case of new build plants, capital emissions for the entire facility are to be included, and as we understand the methodology no allocation is to be performed between energy generation and carbon removal (i.e. all construction emissions would be counted in the project emissions).

The gross amount of CO_2 injected is preferably to be reported by the storage operator, so that any losses in the transport and storage system are accounted for implicitly and need not be directly assessed. In the absence of this information, gross CO_2 injection should be calculated as gross CO_2 captured minus any fugitive emissions minus any CO_2 captured from non-biogenic sources (ancillary fuels).

The methodology suggests a twice renewable crediting period of 15 years (i.e. a maximum total certification period of 45 years).

The methodology states that it embodies a principle of conservativeness, i.e. the principle that it is better to undercount than to risk overcounting benefits.

3.10.2 Indirect emissions and leakage

The methodology calls upon the project proponent to consider leakage emissions from:

- Upstream/downstream emissions due to e.g. changes in forestry practice associated with supplying the BECCS facility (upstream) or expansion of CO_2 transport infrastructure (downstream).
- Market leakage, for example if the consumption of a fraction of the energy produced by a biomass power plant leads to reduced electricity output to the grid and increased production of higher carbon energy elsewhere. Market leakage is presumed to be zero for new build plants, as the energy that is consumed by the CCS unit would not have been produced in the baseline. If a retrofit CCS project is associated with reduced energy output, a leakage assessment must be made. The leakage is presumed zero in energy markets that operate in cap-and-trade schemes, on the basis that any increase in energy production emissions would have to be compensated elsewhere under the cap and trade. Otherwise, energy leakage emissions shall be calculated as energy consumption multiplied by the annual average emissions intensity of the local grid (though for average grid electricity GHG intensity below 18 gCO_2e/MJ the methodology allows this term to be set to zero). For CHPs, an analogous calculation is required for heat. It is not explicit what assumption should be made on the GHG intensity of local heat production, but we understand from the developers that they would expect an average emission factor to be directly assessed for the heating network that the heat is displaced from.
- Ecological leakage, which covers ecologically-mediated indirect effects. An example would be if water removals for biomass production led to lowering of the water table at a hydrologically connected wetland. The methodology calls for any such issues to be assessed through environmental impact assessment.

The methodology also identifies 'activity-shifting' emissions as a form of leakage (this would include indirect land use change), for example emissions from the case that other agricultural activity is displaced from land on which biomass is to be produced. These emissions are to be treated as non-material by hypothesis, based on the claim that the sustainability requirements would protect against such land sector leakage.

3.10.3 Additionality and baselining

The additionality assessment is based on a regulatory surplus test, and a specified form of financial additionality assessment. These is identified as a form of 'standardised approach in the language of the ICVCM; the main differences between the proposed approach and the ICVCM standard for investment analysis appear to be that the methodology excludes a common practice analysis, and that a full investment analysis is only required in certain cases. A project will be considered additional if it passes a regulatory surplus test and:

- Receives no additional financial support (beyond CDR sales) from the private sector or government;
- Receives additional financial support from government but not the private sector, and the government financial support is predicated on participation in the voluntary carbon market;
- Receives additional financial support from the private sector (and potentially also the government), but an auditor's statement confirms that the project would not proceed without carbon market revenues.

There is no prescription of the approaches that should be followed by the auditor in assessing whether the project would receive without carbon market revenues, e.g. there is no guidance on allowable assumptions on internal rate of return on capital expenditure.

The methodology defines the baseline as "would have happened in the absence of a carbon removals project". Baselines are defined for two different cases – 'retrofit' and 'new-build' BECCS. Retrofit is identified as the installation of carbon capture equipment on an existing biomass energy facility. The case of simultaneously retrofitting a fossil energy plant to biomass burning and CCS is not addressed, but we understand that this will be added when the 1.0 version of the methodology is published. Installing CCS at any plant that has been operational for less than 36 months[72] will be treated as new build.

While the methodology describes the baseline, emissions reductions are not defined as project emissions minus baseline emissions as in some methodologies. Rather, the baseline (retrofit or new build) affects the determination of what is to be counted as a project emission. For new build, the emissions from facility construction must be included in the emissions assessment. For retrofit, any reduction in renewable energy output must be considered as 'energy leakage'.

3.10.4 Long-term storage and liability

The methodology states that CO_2 stored subject to the outlined requirements may be considered permanent (i.e. with minimal risk of reversals). The methodology applies only for sequestration in regions identified as having robust regulatory systems in place to govern carbon storage (the EU/EEA, UK and USA).

3.10.5 Sustainability

The draft methodology includes sustainability requirements on forestry biomass, but states that requirements on agricultural biomass will be added later. The forestry sustainability requirements are heavily informed by the mandatory requirements of the RED II/III.

Applicants are required to undertake a carbon stock assessment for any 'sourcing area' from which forest biomass is obtained for a BECCS project, and must demonstrate that carbon stock in standing above ground biomass is stable or increasing. Below ground biomass, litter biomass and soil carbon may either be quantified, or else evidence may be provided 'that such carbon stocks are not negatively impacted'. It is not explicit what evidence would be required in this regard.

The carbon stock assessment requirements echo a requirement in Article 29(7) of the RED II. Similarly to RED II, the stability of carbon stocks may be demonstrated at the national level.

There is also a requirement that the sourcing area is subject either to national sub-national sustainable forestry laws or to a management plan to ensure[73]:

- Legality of operations [Art. 29(6 a/b i)];
- Forest regeneration [Art. 29(6 a/b ii)];
- That designated nature protection areas are protected; [Art. 29(6 a/b iii)];
- That harvesting considers maintenance of soil quality and biodiversity according to sustainable forest management principles, including [Art. 29(6 a/b iv)];
- Avoiding harvesting of stumps and roots [Implementing Regulation 2022/2448 Art. 3(1 b iv 3), Art. 4(b iv 2)];

[72] We understand that this will be increased to 48 months in future versions.

[73] Related RED II requirements are indicated with square parentheses.

- Avoiding harvesting on vulnerable soils [Implementing Regulation 2022/2448 Art. 4(b iv 3)];
- Local maximum thresholds for clearcutting are respected [Implementing Regulation 2022/2448 Art. 4(b iv 7)];
- Deadwood harvesting adheres to locally and ecologically appropriate retention thresholds [Implementing Regulation 2022/2448 Art. 4(b iv 6)];
- Impacts on soil quality, biodiversity features and habitats are minimised [Implementing Regulation 2022/2448 Art. 4(b iv), Art. 4(b iv 5)]; and,
- That harvesting maintains or improves the long-term production capacity of the forest. [Art. 29(6 a/b v)].

The draft methodology also echoes the RED III[74] prohibitions on obtaining biomass from land with certain statuses:

- Primary forest and old growth forest;
- Highly biodiverse forest;
- Highly biodiverse grassland; and,
- Lands recently converted from peatland or wetland status, unless on peatland with evidence that biomass collection does not involve drainage of undrained soil.

The draft methodology goes beyond the core requirements of RED II by prohibiting the use wood appropriate for use in sawtimber or veneer given the nature of the market in the sourcing area (this echoes an exclusion from Annex IX Part A of the RED II, which prohibits the use of those materials as feedstock for biofuels receiving extra incentives as 'advanced'). The draft methodology also adds an exclusion for biomass from any country with a Corruption Perception Index (CPI) lower than 50 unless the supplier has adopted an appropriate 'Supplier Code of Conduct'. Countries with a CPI below 50 include Romania, Bulgaria, Malaysia and China.

It does, however, note the claim that improved management including biomass removal may provide benefits in high ecological value forests prone to 'natural disturbance events', which presumably refers primarily to fire and disease/infestation, and suggests that the standard may be expanded to allow such material in a future revision.

3.10.6 MRV

Projects must be based on a project design document that includes a monitoring plan. Projects must be independently validated (generally at the same time as first verification) to show that the project design is consistent with the requirements of the methodology. At least once per year the project proponent must submit a full verification report to an appropriate verifier accredited either pursuant to ISO 14064-3, to the CDM standard for designated operational entities or by a 'relevant' governmental or intergovernmental regulatory body. Verification is to be carried out to a reasonable level of assurance.

For biomass sustainability monitoring, a mass balance approach to chain of custody is permitted[75] and compliance should be demonstrated at least annually by either certification, demonstrated regulatory compliance (e.g. presumably RED compliance would be considered

[74] Note that RED III adds limitations on the use for energy of forest biomass from highly biodiverse areas that were not present in the RED II. The Drax-Stockholm Exergi methodology reflects the more stringent RED II requirements.

[75] A segregated supply chain is also allowed, but this can be thought of as a special case of mass balance.

adequate to demonstrate compliance with the requirements) or independent ISAE 3000 limited assurance.

In the event of non-compliance being demonstrated for any consignment, then no removal certificates would be awarded for CO_2 volumes derived from those consignments.

3.11 JOGMEC CCS guideline

In 2022 the Japan Oil, Gas and Metals National Corporation (JOGMEC), a Japanese government independent administrative institution, released a guideline for assessment of CCS projects[76] as part of the "JOGMEC Carbon Neutral Initiative". JOGMEC states that, “The CCS guideline has been set to harmonise with current international standards and is NOT intended for regulatory purposes. JOGMEC does not certify emissions reductions.”

The objectives of the guideline are to provide recommendations for: 1) the design of geological CO_2 storage projects; 2) evaluation of CO_2 storage resources; and, 3) calculation of the amount of GHG reduction generated from CCS projects.

The JOGMEC standard is based on the ISO 27914:2017 standard[77] for geological storage of CO_2, and the scope is limited to the storage site; the standard does not cover the capture and transport of the CO_2 and is therefore agnostic about whether projects represent CO_2 reductions or removals. We have reviewed the first edition of the guideline, dated May 2022, for this review.

3.11.1 Quantification

The net emission reduction from the project is characterised as the amount of CO_2 captured, minus the amount of CO_2 generated to obtain energy for the associated processes and the amount of CO_2 leaked in the process of capture, transport and storage. Nitrous oxide emissions are excluded from the scope as insignificant. The guideline refers to the ISO 14064 standard and to the Alberta protocol for quantification of CCS project emissions.

The boundary of a project is defined as enclosing the CO_2 capture system, the necessary transportation systems including installations for loading and unloading and for maintaining pipeline pressure, and the final CO_2 injection and storage systems. All emissions within the project boundary must be quantified.

3.11.2 Additionality and baselining

The JOGMEC guideline does not actively consider additionality, and assumes a baseline in which there is no CCS activity.

3.11.3 Long-term storage and liability

JOGMEC refers to locally applicable standards and coordination with the competent authority to determine the period of monitoring necessary before management responsibility can be transferred to a public body (referencing the CCS Directive, for example). A monitoring plan must be developed, and risk management procedures should follow the relevant ISO standards.

[76] English executive summary available at https://www.jogmec.go.jp/content/300378207.pdf

[77] https://www.iso.org/standard/64148.html

3.11.4 Sustainability

The JOGMEC guideline calls for operators to ensure environmental protection at CCS sites, but does not set specific sustainability requirements.

3.11.5 MRV

The JOGMEC MRV requirements are based on the relevant ISO standards.

3.12 Gold Standard

The Gold Standard (GS) is a voluntary carbon offset programme that focuses, exclusively, on projects that provide lasting social, economic, and environmental benefits in line with the UN Sustainable Development Goals (SDGs). The GS programme is applicable to both voluntary offset projects and to CDM projects.

The GS was established in 2003 and is a well-known standard that aims to ensure environmental integrity and contribution to sustainable developments – historically for carbon reduction projects.

The GS currently presents two carbon removal methodologies[78] – one that is nature-based (soil organic carbon enhancement with pulp and paper mill sludge) and a technology-based one (accelerated carbonation of concrete aggregate). There is also a draft methodology for biomass fermentation with CCS[79].

The accelerated carbonation of concrete aggregate[80] methodology[81] was developed by Neustark AG and has been available to projects since 7th March 2022. It uses either direct or indirect mineral carbonation before it enters the downstream processes for permanent storage in the form of calcium carbonate ($CaCO_3$). Direct mineral carbonation resembles the natural process of weathering of concrete structures, but with an increased reaction rate, while indirect mineral carbonation involves extracting the cement phases by means of a solvent and then carbonating it.

3.12.1 Quantification

In the case of projects involving both biogenic and fossil CO_2, the amount of biogenic CO_2 is determined according to the MRR of the EU ETS or equivalent.

Project emissions include GHG emissions "from onsite power or energy consumption for the purpose of sourcing, processing and transportation of CO_2, operation of carbonation plant and/or transportation of concrete aggregate or regenerated sand from recycling facility".

Where indirect mineral carbonation processes take place, the project boundary is extended to include GHG emissions from solvent supply. Emissions from waste treatment or reuse of demolition concrete can be ignored if they incorporate the steps outlined in the project and baseline scenario. However, any additional processes must be quantified unless justified otherwise.

Baseline emissions are defined to be equivalent to the amount of CO_2 sequestered in carbonated concrete aggregate by applying direct or indirect mineral carbonation, i.e. the amount of CO_2 that would be in the air if not sequestered through carbonation, and the

[78] https://www.goldstandard.org/blog-item/innovating-carbon-removals

[79] https://www.goldstandard.org/our-work/innovations-consultations/methodology-biomass-fermentation-carbon-capture-and-geologic

[80] Concrete aggregate is also referred to as demolished concrete.

[81] Carbon Sequestration through Accelerated Carbonation of Concrete Aggregate – Gold Standard for the Global Goals

methodology notes that, "it would be correct to apply the term 'Project Sinks' instead of the term 'Baseline Emissions'". The methodology provides for both an ex-ante and an ex-post assessment of CO_2 sequestration. The ex-ante calculation to assess the 'gross sink capacity' is based on multiplying the mass of each type of material by a 'sink factor' for that material, i.e. the potential CO_2 sequestration per kilo of a given type and grain size of material. This ex-ante value is used to validate the ex-post assessment of CO_2 sequestered. The ex-post assessment is based on differencing between the amount of CO_2 fed into the carbonation plant from the amount of CO_2 exiting the carbonation plant. The ex-post CO_2 uptake value is used in calculating the emissions reductions from the project, with 'project emissions' and 'leakage emissions' subtracted from the quantity of CO_2 sequestered.

Project emissions are defined as the sum of emissions from operating the carbonation plant, from energy consumption associated with evaporation of CO_2, and associated with the supply of solvents for the indirect carbonation process (if applicable). Electricity consumption is assessed with an emissions factor representative of the national or regional grid, determined by application of the CDM tool to calculate the emission factor of an electricity system.

Lifecycle emissions for the energy used upstream of the project facility (e.g. energy for crushing grains of material, for material transport and for capture and transport of the utilised CO_2) are identified by the methodology as 'leakage emissions'.

Emission reductions are calculated as the deduction of project and leakage emissions in the monitoring period from the total amount of CO_2 sequestered in carbonated concrete aggregate by applying direct or indirect mineral carbonation with biogenic CO_2.

The project boundary includes the:

- physical site of concrete recycling facility;
- carbonation plant; and,
- source of $CO_{2;}$ and,
- end products site.

The sources of CO_2 are either of DAC or biogenic origin. For any projects that require the use of non-biogenic sources of CO_2, further approvals must be obtained. The methodology would also require revisions to accommodate this.

3.12.2 Indirect emissions and leakage

There is no consideration of indirect emissions.

3.12.3 Additionality and baselining

GS requires the demonstration of additionality on a financial basis[82].

GS allows the use of CDM additionality tools, as well as permitting projects to submit self-developed additionality tools for approval by the GS[83]. For example, GS projects are permitted to use the CDM baseline and additionality tools:

- TOOL 02 "Combined tool to identify the baseline scenario and demonstrate additionality";
- TOOL 11 "Assessment of the validity of the original/current baseline and to update of the baseline at the renewal of the crediting period".

[82] Strictly, this requirement only applies to projects, "seeking to use certification to attract finance or issue market products through the issuance of Gold Standard Certified Products or Impact Statements".

[83] Cf. section 2.3 of the 'Gold Standard Toolkit v2.2, https://www.goldstandard.org/sites/default/files/gsv2.2_toolkit.pdf

The evidence required to demonstrate additionality needs to be in line with the requirements of the chosen approach.

Regarding determination of baseline scenario, all realistic alternatives (there are ten listed in the methodology, but alternatives are not limited to them) are assessed. The one with the lowest emissions is then selected as the most likely one, i.e. no CO_2 is captured and supplied to a carbonation plant.

The standard clarifies that different approaches for additionality demonstration may also be submitted for approval.

In addition to demonstrating the financial additionality when the project first registers, projects shall demonstrate Ongoing Financial Need (OFN) at the certification renewal. The OFN is required for projects that wish to renew their crediting period to ensure that the finance derived from the certification is – and remains – material to the ongoing sustainability of the project.

3.12.4 Long-term storage and liability

For the carbonation methodology, project developers are required to provide evidence on the end use of the produced calcium carbonate. $CaCO_3$ as a filler material as part of the construction industry is considered as permanent storage. For all other applications of $CaCO_3$, storage is considered as non-permanent by default. Some exceptions may be granted only if it can be evidenced that the CO_2 is permanently stored.

Under the methodology, $CaCO_3$ is not allowed to be used in clinker production as the process would release the CO_2 which is already stored through the carbonation.

CO_2 leakage emissions from the carbonation process are considered “neutral”[84] and are not included in the calculation of the total project and leakage emissions.

The project developer is required to communicate in a written form to all project participants details about ownership rights and claiming emissions. In the cases where the project developer is different from the end user of the technology, the end user is clearly notified in a written agreement that they are not allowed to claim emissions from the project.

In addition to legal title and ownership, the project developer is also required to “demonstrate where required uncontested legal rights and/or permission concerning changes in use of other resources required to service the project[85]”. Disputes must be notified to GS by the project developer and resolution is required before further project implementation.

3.12.5 Sustainability

To achieve certification with GS, projects are required to be aligned with Eligibility Principles and Requirements[85].

According to Principle 1 “Contribution to climate security and sustainable development”, all projects are required to have a positive impact when reviewed against the SDGs, meaning the project must demonstrate its positive contribution to SDG 13 plus two other SDGs, which equates to the sustainability requirements from the VCS. The SDG impacts shall not be a “one off” or resulting during design, construction or decommissioning phase – instead they shall be demonstrated as a “primary effect”.

[84] This is because the methodology is only applicable for DAC and biogenic sources of CO_2.

[85] 101_V1.2_PAR_Principles-Requirements (goldstandard.org)

The tech-based carbon removals methodology is marked with SDG 13 and stands for taking an urgent action to combat climate change and its impacts. SDG 13 is defined as "Emissions Reductions or Removals and/or Adaptation to climate change".

Three options are outlined in the GS Principles & Requirements as to how SDG impacts can be demonstrated:

- **Option 1** – for identified SDG impacts, the project developer reviews and selects the SDG targets and indicators that are most relevant to demonstrate how the project can impact these. New indicators can also be proposed, but only with suitable justification.
- **Option 2** – by following a GS-approved SDG tool.
- **Option 3** – by following a GS-approved Methodology published on the website. Project developers may submit a methodology for review and approval (there is the possibility to develop a project and a methodology at the same time).

3.12.6 MRV

In order to achieve GS Certified Project status, the project shall follow the monitoring plan, approved during Design Certification, that is also submitted for verification[85].

The project developer carries the responsibility of meeting the monitoring requirements and that all data required is available.

If the carbonation plant is located in the same facility as where the source of CO_2 is, then monitoring includes the total amounts of CO_2 production and consumption for carbonation.

The monitoring methodology includes an outline of data and parameters monitored which – as with other standards reviewed in this review – includes sources of data, measurement procedures and monitoring frequency for each one. All data required for performance monitoring is to be stored electronically and kept for two years after the end of the last crediting period.

The parameter "End use distribution" (CSAC 41) is used for the ongoing monitoring of the end use of concrete aggregate.

The monitoring methodology also includes an outline of data and parameters not monitored which includes averages, representative and default values, emission factors etc.

3.13 Isometric Protocols

Isometric offers two products - a carbon removal registry and a science platform. The Isometric Science Platform, designed as a 'community resource', brings buyers, suppliers and academia together. Its main purpose is to let suppliers of carbon removal data and protocols share their early findings with the scientific community who can then provide feedback. Isometric hosts protocols which are initially developed by other suppliers. Isometric Protocols are shared at various stages of development and feedback is invited from stakeholders via consultation and comments. The Isometric Registry (launching late 2023) will record carbon removals credits verified against the Isometric standard.

Here, we have reviewed version 1.0 of the Isometric Standard, dated 4 October 2023. Isometric's website also hosts a combination of protocols developed by Isometric itself and protocols developed by third party carbon removals operators. At the time of writing, there were not yet any finalised protocols published online on the Isometric website. Through the survey, Isometric shared a 'Bio-Oil Sequestration Protocol for Carbon Dioxide Removal Monitoring, Reporting, & Verification' (henceforth 'Bio-Oil Protocol') with us that it has developed, and we have used this as an example protocol in the discussion in this section.

Note, however, that this protocol is currently framed as applicable only to storage sites in the United States.

3.13.1 Quantification

In general, removals are to be calculated as the difference between project emissions and a counterfactual baseline scenario.

The Isometric standard requires all protocols to include a procedure for the incorporation of uncertainty. This may be done by conservative estimates of input parameters (set at the $16^{th}/84^{th}$ percentile as appropriate), by 'variance propagation' (using a removals estimate at least one standard deviation below the mean estimate) or by Monte Carlo analysis (again using the 16^{th} percentile of the estimate of removals, or by another agreed approach (as we understand the mineralisation protocol, it addresses uncertainty and conservativeness in a bespoke way through an 'uncertainty discount (see below section 3.13.4) and by excluding certain unmeasurable potential removals).

The Bio-Oil Protocol defines the total net CO_2 removal as the sum over time of the amount of carbon stored in bio-oil multiplied by 44/12 to give CO_2 equivalent, minus CO_2e emissions associated with the bio-oil storage process, minus any reversals. Process emissions are to be assessed on a lifecycle basis and include feedstock-associated emissions, transportation emissions, feedstock conversion emissions and injection emissions. The amount of bio-oil injected must be measured by using a calibrated scale to weigh the difference between the weight of a truck arriving at the facility and the weight of the truck leaving after the material has been offloaded for injection. Operators are also expected to log any spills and deduct spilled quantities from the amount injected. The carbon fraction in the injected bio-oil must be assessed by laboratory analysis, with a minimum of one sample analysed per batch.

A survey respondent also referred to an enhanced rock weathering methodology which is still under development and not yet published. The respondent argued that modelling of CO_2 removals through enhanced rock weathering is currently subject to considerable uncertainty with a tendency to overestimation, and stated that the forthcoming approach would introduce a more robust system of on-site measurement requirements, which would differentiate the Isometric standards from other available standards. The respondent argued that an improved model could potentially be calibrated to the results of initial test projects, allowing a reduction in measurement requirements in due course.

The standard also requires protocols to consider leakage emissions, defined as "GHG emissions outside the defined project boundary that occurs as a result of the Project activity". This includes lifecycle emissions for inputs and downstream emission associated with, for example, storage.

3.13.2 Indirect emissions and leakage

The Isometric Standard states that potential GHG increases outside the project boundary should be considered, but is not explicit about whether and how economic leakage should be considered. The Bio-Oil Protocol, however, explicitly identifies indirect land use change as within the GHG emissions scope. Assessment of feedstock emissions is to be based on a 'Feedstock Framework'[86], which requires a consequential approach to assessing feedstock emissions to be adopted (as opposed to attributional approaches). The Feedstock Framework requires biomass feedstocks to be subjected to market analysis with a view to identifying potential market-mediated emissions. For waste/by-product materials, this would include an assessment comparable to the rigid inputs assessment required under the

[86] Isometric also shared a draft version of this document through the survey.

Innovation Fund. The Feedstock Framework says that it does not currently allow feedstocks purpose grown for carbon removal activities to be used.

3.13.3 Additionality and baselining

Isometric defines project additionality[87] as meaning that a project causes "a climate benefit above and beyond" what would have happened in a no-intervention baseline. The Isometric standard identifies three pillars of additionality (financial, regulatory and environmental[88]) that must be satisfied in order to treat a project as additional:

- Financial additionality can be demonstrated if either a) removals are the only source of revenue for the project, or b) that without carbon finance revenue the project has an IRR that is zero or lower or that is below the cost of capital or required return on equity for the project, and that the revenue from carbon credits will make that IRR positive or above the required rate of return (as appropriate), although there is provision made for project proponents to justify a higher IRR for the assessment. The standard is not prescriptive about what target IRR can be considered acceptable.
- Regulatory additionality requires that the project is not legally required, though removals beyond the minimum legal requirement may be certified.
- Environmental additionality is defined as a net negative climate impact, which is presumably trivial for any carbon removal project generating credits, and therefore does not seem to be a substantive addition to the additionality framework.

The Bio-Oil Protocol allows for a project to be identified as 'automatically' additional if the only source of revenue for the project is carbon finance, the lifecycle emissions are net negative[89] and the project passes a regulatory surplus test. If there are other sources of revenue, the project would be subject to financial additionality testing based on project financials, and this test may be based on the CDM investment analysis tool.

The baseline will be the emissions balance had the project not taken place, with specific baselining requirements defined in each protocol. The Bio-Oil Protocol requires that the consequential considerations detailed in the Feedstock Framework should be considered in constructing the baseline. This also includes potential temporary reductions in counter-factual storage for the case that the biomass feedstock would have been a basis for temporary CO_2 storage in the counterfactual case.

3.13.4 Long-term storage and liability

The Isometric standard calls for projects to demonstrate durability of removals of at least 1,000 years, although it allows for projects with less durability to be reviewed on a 'case by case basis'. In the Bio-Oil Protocol, detailed requirements are set on the geological storage site (including closure) and the characteristics of the bio-oil, with a view to minimising the risk of reversals/maximising durability. A post-injection monitoring plan is required. Buffer pools will be created for all project proponents, and credits cancelled from the buffer pools in the case of reversals. Buffer pool size is to be determined by the assessed risk of reversal, up to 20% for the highest-risk projects (risk of reversal is to be assessed based on a questionnaire that is given in an appendix). There may be some issues in the practical application of this tool in the current Standard; notably, as we understand the questionnaire, it is currently

87 Isometric — Glossary

88 In fact the text currently reads "financial, regulatory and financial", but this is a typo.

89 This condition ought to be satisfied by any project able to generate carbon removal credits.

impossible for a project for which reversals would not be directly observable to be identified as high risk[90].

3.13.5 Sustainability

The standard suggests (but does not require) an environmental impact assessment (EIA) and social impact assessment (this is mandatory if required by local regulation). The standard states that projects must demonstrate that they create no net social or environmental harm and identifies a range of issues to be considered, but it is not clear how this no net harm requirement would be operationalised. The Bio-Oil Protocol requires applicants to provide information on sustainability considerations such as biodiversity, food security, loss of arable land, deforestation, impact on indigenous communities or culturally sensitive lands, and health and safety issues including bio-oil handling, but is also not explicit about how the no net harm requirement would be assessed in the event that a negative sustainability impact was identified.

3.13.6 MRV

Monitoring should be based on a full risk assessment undertaken to identify all possible mechanisms that could lead to reversals. The standard states that monitoring regimes should reflect relative uncertainty in technologies that may not previously have been widely applied. Monitoring reports should be made publicly available through the registry.

Validation and verification are to be conducted according to ISO 14064-3 and ISO 14065. All validation and verification bodies must demonstrate accreditation either from an International Accreditation Forum member, a relevant governmental or intergovernmental regulatory body, or be approved by Isometric directly. Projects must undergo initial project validation, and the verification of all claimed removals.

3.14 Additional relevant sources

The findings presented in this review have been drawn from the regulations and standards included in the scope of this review. Although these were identified as relevant and/or well-established and therefore useful for the purpose of informing the development of the certification methodologies, it is acknowledged that other relevant methodologies are available, as well as a wealth of reports, guidance documents and other literature that could be pertinent to the development of certification methodologies.

3.14.1 Other standards

Three additional private standards or initiatives for certification or generation of carbon removals have been identified:

1. **C-Capsule**[91] and
2. **Riverse**[92]
3. **Carbon Standards International (including the European Biochar Certificate)**[93]

[90] This is because a score of 6 or more is required to identify a project as high risk, but projects for which reversals would not be directly observable are only required to answer questions with a maximum associated score of 4.

[91] https://www.c-capsule.com/

[92] https://www.riverse.io/

[93] https://www.carbon-standards.com/en/home

While these are not reviewed in this document, the documentation associated with these standards may still be considered in the process of developing EU certification methodologies.

3.14.2 Other documentation relevant to certification

The following documents have been identified as relevant to specific project types and/or elements of GHG assessment. This is not intended as a comprehensive list of other relevant documents, and additional documents will continue to be considered in the process of developing certification methodologies. The list includes:

- In relation to fugitive methane emissions from on-site combustion equipment, the **VCS DAC draft methodology** makes reference to *US EPA Mandatory Reporting of Greenhouse Gas Emissions* which allows a default calculation based on component counts and respective emission factors.
- The **US NETL**[94] produces best practice guidance on various aspects relating to geological storage.
- The **California CCS protocol** under the Low Carbon Fuel Standard (LCFS), which describes requirements and boundaries of CCS projects.
- The **US EPA Subpart RR (Geologic Sequestration of Carbon Dioxide)**[95] in which guidelines for measurement and reporting of CO_2 sequestered into subsurface geologic formations are laid out.
- The **Bison Project (Wyoming, US) by Carbon Capture** is a running DACCS facility; an analysis of the certification methodology based on the ISO 14064-2 could provide further insights on a detailed level for the definition of the scope of a project for calculation of project emissions.
- The Integrity Council for the Voluntary Carbon Markets (ICVCM) publishes a set of **'core carbon principles'** (which overlap with the QU.A.L.ITY criteria) described as "global benchmark for high-integrity carbon credits".
- Carbon Direct and Microsoft have published "Criteria for High-Quality Carbon Dioxide Removal", which are described as helping to, "advance a common definition of high-quality CDR by providing widely applicable quality benchmarks".
- The Swedish Environmental Research Institute provides **Tier 1 and Tier 2 calculators for CO_2 uptake in concrete** based on IPCC guidelines.
- The **"CDR Primer"** provides a glossary and discussion of relevant concepts in carbon dioxide removal[96].
- The **CORSIA** (Carbon Offsetting and Reduction Scheme for International Aviation) Regulation of the International Civil Aviation Organisation (ICAO), which has a membership of 192 countries, contains rules relating to eligible emissions offsets to be surrendered against aviation decarbonisation commitments.

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[94] https://www.netl.doe.gov/carbon-management/carbon-storage/strategic-program-support/best-practices-manuals

[95] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-RR

[96] https://cdrprimer.org/

4 Key areas of difference among existing standards

The regulations and standards considered in Sections 2 and 3 cover a wide range of issues, project types and certification approaches. While the regulatory approaches have only limited areas of overlap, the reviewed private standards and non-EU public frameworks necessarily cover the same issues, and therefore provide differing visions of how the elements of the QU.A.L.ITY framework might be implemented. In this section, we highlight a subset of issues that have been identified as potentially relevant to the development of EU certification methodologies for industrial carbon removals in which there are clearly differentiated approaches among the standards, and briefly identify which of the standards reviewed have currently adopted different approaches.

Some questions are relevant to only some standards (e.g. because there is a lack of published methodologies for some types of projects). Where a particular question is not relevant to one of the standards considered (e.g. ISO, GHG Protocol and JOGMEC are not certificate issuing standards), or if it was unclear to us how a question was handled by a specific standard, then those standards are excluded from the relevant tables. In some cases, more than one answer may be applicable to a single standard and therefore a standard may be listed more than once in a table (e.g. VCS allows either regional average electricity emission factors or the use of the CDM tool for assessing electricity emission factors). As the focus in this section is on identifying differences between standards, we have not included the regulatory frameworks in the tabulation below, however in some cases we have mentioned relevant regulations in the introductory text.

4.1 Quantification and boundaries

There is considerable comparability between standards in setting the basic principles of removal quantification. While terminology varies, there is broad agreement that the assessment of generated removals should reflect the difference between removals in a project scenario as compared to some form of baseline, and that the scope of the GHG assessment should at least include all on-site emissions, as well as some characterisation of lifecycle emissions associated with the generation of energy and inputs for use by a project.

4.1.1 Should emissions associated with 'capital goods' be considered?

As well as emissions associated with producing inputs and energy for use in the operational phase of a project, there are emissions associated with production of equipment and construction of buildings. Some of the standards considered in Sections 2 and 3 include these, while others regard them as out of scope. For example, in the RED II and under the Innovation Fund, emissions associated with capital goods are considered out of scope.

Yes, emissions associated with 'capital goods' should be considered	No, emissions associated with 'capital goods' are out of scope
ISO	CDM
Puro	VCS (dependent on methodology)
VCS (dependent on methodology)	ACR
CCS+	JOGMEC
Climeworks/Carbfix	Gold Standard
Drax-Stockholm (new builds)	

4.1.2 How should the GHG intensity of consumed electricity be assigned?

It is common in lifecycle accounting to assume that consumed electricity imported into the project is associated with the average GHG intensity of the local or national grid from which it is obtained. However, this may not give a good characterisation of the marginal impact of additional electricity demand. There is also a question about how and when consumed electricity may be treated as renewable and/or as zero carbon, e.g. whether electricity purchased with a renewable Guarantee of Origin (GoO) or on a renewable power purchase agreement (PPA) may be treated as zero carbon. The RED II sets limitations on when the electricity used for renewable fuels of non-biological origin may be treated as renewable and as zero carbon. In contrast the Innovation Fund, because it is forward looking and anticipates a fully renewable electricity supply, allows all consumed electricity to be treated as zero carbon.

Electricity emission factor based on national/regional grid average	Renewable power treated as zero carbon	Electricity emission factor assessed with CDM tool	Choice of electricity emission factor based not explicitly constrained
VCS CCS+ ACR GCC	CCS+ (direct connection to off-grid source) Drax-Stockholm (biomass supply emissions to be considered)	CDM VCS GCC	ISO Puro Climeworks/Carbfix ('literature derived') JOGMEC

4.1.3 Are indirect emissions (in the sense used in the proposed CRCF) considered?

Are indirect emissions due to 'economic leakage'/market mediated effects considered in project emissions.

Yes, indirect emissions are considered	No, indirect emissions are out of scope
ISO Puro VCS ACR (AFOLU) Drax-Stockholm	CDM CCS+ (available methodologies) ACR (other) Climeworks/Carbfix GCC JOGMEC

4.1.4 What assessment of uncertainty in project removals is required, and how is uncertainty handled?

Are projects required to characterise any uncertainties in the calculation of project or baseline emissions, and if so, are projects with higher levels of uncertainty subject to any reduction in the creditable quantity of removals? Does the standard state that applicants should follow some form of principle of conservatism (i.e. that in the event of uncertainty applicants should err on the side of being more likely to underestimate than to overestimate removals)?

Uncertainty assessment is required, and projects with greater uncertainty receive fewer credits	Uncertainty assessment is required, but there is no standard requirement to reduce d	Nominal principle of conservativeness, but no direct uncertainty assessment	Projects are not required to assess uncertainty
Isometric ACR VCS (AFOLU, where there is market leakage risk)	CDM ISO Puro (methodology specific) VCS ('where applicable') GCC Drax-Stockholm JOGMEC	Puro (methodology specific) CCS+	Climeworks/Carbfix (but measurement uncertainty should be limited below 5%)

4.1.5 What is the initial certification period, and can projects be recertified?

There are various periods allowed on initial certification. Most standards allow at least one cycle of recertification, but most do not allow indefinite recertification.

Crediting period / Renewal amount	Up to 5 years	6-11 years	11-21 years	Above 21 years
No renewal		CDM (up to 10 years)		GCC (life of facility)
1 renewal	Isometric			
Up to 5 renewals		CDM (up to 7 years, 2 renewals) VCS (non-AFOLU) CCS+	Drax-Stockholm	VCS (AFOLU)
Unlimited renewal	Puro	ACR (CCS)		

4.1.6 Are there rules on double counting of benefits, and do they extend to ‘double claiming’?

Certification systems for emissions reductions and removals are associated with systems to surrender those certificates in order for a party to claim reduced emissions either in a regulatory context (e.g. surrendering CERs from CDM to show compliance with a nationally determined contribution) or as part of sustainability reporting (e.g. a company claiming to achieve net carbon neutrality). All certification schemes have systems to ensure that a certificate may only be surrendered once, but there may be additional requirements prohibiting certified reductions from being counted in two contexts – for example in the case of CCS prohibiting a reduction from being certified and sold, as well as being used as part of compliance with a cap and trade obligation for the party capturing the CO_2. There may also be limits placed on the way that claims can be made – for example, a party capturing 100% of its CO_2 and selling the credits to be surrendered by a third party would not then be able to claim that it itself had zero carbon emissions. We note that there is a related issue regarding whether an emission reduction that is reflected in national accounting towards a Nationally Determined Contribution (NDC) may also be claimed by a corporate entity. However, we have not reviewed the position of standards on this point.

Double counting prohibited	Double counting and double claiming prohibited
GCC CDM VCS (additional rules on double claiming become active in 2024) CCS+ (follows VCS) GHG Protocol Drax-Stockholm	Puro Gold Standard (‘minimise risk of double claiming’) Isometric ACR

4.2 Additionality and baselining

All of the standards considered require some form of demonstration of additionality and either explicitly or implicitly require some sort of baseline emissions to be considered in the calculation of net carbon removals. However, the implementation of these requirements varies.

4.2.1 Is there an accommodation to use some form of performance standard or positive list instead of a full additionality assessment?

The proposed CRCF framework anticipates that additionality will be demonstrated either by assessing performance against a standardised baseline (some standards refer to this approach to additionality as a ‘performance standard’) or by showing that a project goes beyond any regulatory requirement and can be shown to take place due to the incentive effect of certification. Among the existing standards, some always require a direct additionality assessment using approaches such as financial additionality and regulatory surplus tests. Others provide options for a direct additionality test, but in some or all cases also allow for projects to be identified as additional based on comparison to a performance standard or because they are included on a curated ‘positive list’ of project types that may always be considered additional.

Direct additionality assessment required in all cases	Some form of performance standard permitted	Positive lists permitted[97]
Puro CCS+	ACR VCS	CDM VCS GCC Gold standard (allows the use of the CDM positive list[98]) Isometric[99]

4.2.2 Which elements of additionality analysis (e.g. financial assessment, regulatory surplus test, common practice analysis) are required?

When a direct additionality assessment is used, it may include elements of financial analysis, barrier test, regulatory surplus test, and/or common practice test[100]. Note that VCS is not placed in one of the groups below as requirements vary considerably between methodologies.

Financial test and regulatory surplus test	Financial test may be substituted by barrier analysis, and regulatory surplus test	Financial test or barrier analysis, plus regulatory surplus test and common practice test	Financial test plus regulatory surplus test and common practice test
Puro Drax-Stockholm Isometric	VCS	CDM Climeworks/Carbfix GCC	CCS+

4.2.3 Where a financial test is required, is the form of the financial analysis prescribed?

Some standards provide a relatively detailed outline for a financial test (e.g. identifying permitted assumptions on internal rates of return (IRRs) or requiring the use of the CDM tool for the assessment of additionality), while some provide only a general outline requirement.

[97] In some cases an entry in a positive list may not alleviated all other requirements, e.g. VCS still require a regulatory surplus test for projects using a positive list under an 'activity method'.

[98] https://globalgoals.goldstandard.org/standards/RC_2019-CDM-Tool-32–Positive-List-of-Technologies-for-Additionality.pdf

[99] Based on use of positive list approach in the microbial mineralisation protocol.

[100] Note that there are also some cases in which a form of common practice analysis is not used as an additional test requirement but rather can be the basis for inclusion in a positive list, e.g.

Requires use of the CDM tools for financial test	A relatively open specification for financial test
CDM CCS+ ACR Climeworks/Carbfix GCC	Puro VCS[101] Drax-Stockholm Isometric

4.3 Long-term storage and liability

4.3.1 What is the minimum period of expected carbon storage that is treated as a removal by the standard?

Standards differ in their interpretation of what may be counted as ‘long-term’, and in whether they are specific about expected durations.

< 100 years	Estimated storage at 100 years	> 100 years	> 1000 years	‘Permanent’
ACR (for AFOLU projects, 40 years)	Puro (biochar and woody biomass burial/terrestrial carbon storage) VCS	GHG Protocol	Isometric Puro (carbonated materials, ERW, geologically removed carbon)	CDM (for CCS) ACR (for CCS) Climeworks/ Carbfix GCC Drax-Stockholm JOGMEC Gold Standard

4.3.2 Can credits be issued based on modelled rates of carbon sequestration/carbon reversal?

Some methodologies allow crediting based on either expected carbon uptake (e.g. for enhanced rock weathering) or expected durability of storage (e.g. for biochar). Others do not make provision for modelled outcomes in this way (either all removals must be ‘provisionally permanent’ at the point of certification, or the question is not identified as relevant for the methodologies in place).

[101] Details may vary between methodologies.

Yes, credits can be issued based on modelled rates of sequestration/reversal	No, credits cannot be issued based on modelled rates of sequestration/reversal	Unclear (may be methodology dependent)
Puro VCS	GCC Climeworks/Carbfix Drax-Stockholm JOGMEC Gold Standard Isometric	CDM ACR

4.3.3 Does the standard require project-specific assessment of reversal risk?

Some standards require reversal risk to be assessed in detail for each project, others either outsource the management of reversal risk to legislation (e.g. relying on the CCS Directive to manage reversal risk for CCS in the EU) or make a generalised assessment of reversal risk (e.g. identifying a technology as low risk), or building expected reversals into the quantification approach (e.g. for biochar).

Yes, project-specific assessment of reversal risk is required	No, project-specific assessment of reversal risk not required	Unclear or methodology dependent
CDM ISO VCS (for CCS) CCS+ ACR Climeworks/Carbfix Gold Standard (based on end use)	Puro Drax-Stockholm JOGMEC Isometric	

4.3.4 Is a buffer pool system in place?

Some systems require credits to be put into a buffer pool, from which they can be cancelled in the event of future reversals, thereby providing insurance that the total number of credits redeemed outside the programme is never more than the total removals achieved. Others contain provisions for credits to be cancelled from 'normal' accounts in the event of reversals. Others have no comparable provision.

Yes, a buffer pool system is in place	Other form of credit cancellation	No buffer pool system or credit cancellation in place
VCS CCS+ ACR	CDM	Climeworks/Carbfix GCC Drax-Stockholm

Gold Standard Isometric		Puro

4.3.5 When does liability for reversals end?

All carbon removals have some risk of reversals, although this risk may be low. Some standards allow project operators to end their liability for reversals immediately that the removals are certified (for example because they consider the risk of reversal to have been built into the quantification methodology), some standards place the emphasis at the end of the crediting period, while some focus after the liability has been transferred to the state (for CCS projects).

Liability for reversal ends immediately after certification	Liability for reversal ends after certification period ends	Liability for reversal ends after transfer of liability to the state	'Never'
Gold Standard (carbonation) Isometric (OAE and other modelled removals)	Puro (ERW, carbonated materials, biochar) Isometric	VCS (for CCS) CCS+ Climeworks/Carbfix (defined requirements for post-closure monitoring, minimum 10 years) GCC Drax-Stockholm JOGMEC Puro (geologically removed carbon)	CDM (based on 2006 proposal) ACR (requirements for ongoing legal instruments through covenants) GHG Protocol (if stocks can no longer be monitored they should be treated as a reversal) Puro (terrestrial storage of biomass)

4.4 Sustainability

4.4.1 What approach is taken to biomass sustainability assessment?

Where standards allow for certification of projects that use biomass for energy (as distinct from AFOLU projects) there are generally requirements on managing the sustainability of that biomass use. In addition to requirements such as identified in the table, sustainability may also be addressed by placing limits on eligible types of biomass (for example the CDM Large-scale Consolidated Methodology for Electricity and heat generation from biomass limits eligible sources to biomass residues, biogas, RDF[102] and/or biomass from dedicated plantations.

[102] Refuse derived fuel.

Biomass sustainability based on RED II	Some form of sustainable forestry certification	A 'no net harm' condition	Other
Drax-Stockholm	VCS (optional)	Puro Isometric	CDM[103] VCS (including option to follow CDM rules for woody biomass) ACR (EIA/SIA)

4.4.2 Can positive co-benefits be recognised?

The proposed CRCF framework seeks to encourage the delivery of environmental co-benefits. Some existing standards include frameworks whereby additional benefits beyond GHG reductions may be acknowledged.

Yes, positive co-benefits acknowledged	No, positive co-benefits not in scope
CDM (sustainable development co-benefits report) Gold Standard (documentation of contribution to SDGs) VCS (required contribution to SDGs) GCC (co-benefits can be offset against sustainability damage in other areas) CCS+ (inherited from VCS) Puro (positive co-benefits recognised in project listings) ACR (documentation of contribution to SDGs)	Drax-Stockholm Isometric

4.5 MRV

4.5.1 Does the standard require a reasonable or limited assurance statement from the verifier?

Assurance opinions can be provided on a limited basis (meaning that the verifier does not find any evidence that a claim is incorrect) or on a reasonable basis (meaning that the verifier states that they have seen evidence that leads them to believe a claim is correct).

[103] Cf. https://cdm.unfccc.int/EB/023/eb23_repan18.pdf

Reasonable assurance	Limited assurance	Unclear/other
Puro VCS CCS+ ACR Gold Standard Drax-Stockholm Isometric		CDM GCC